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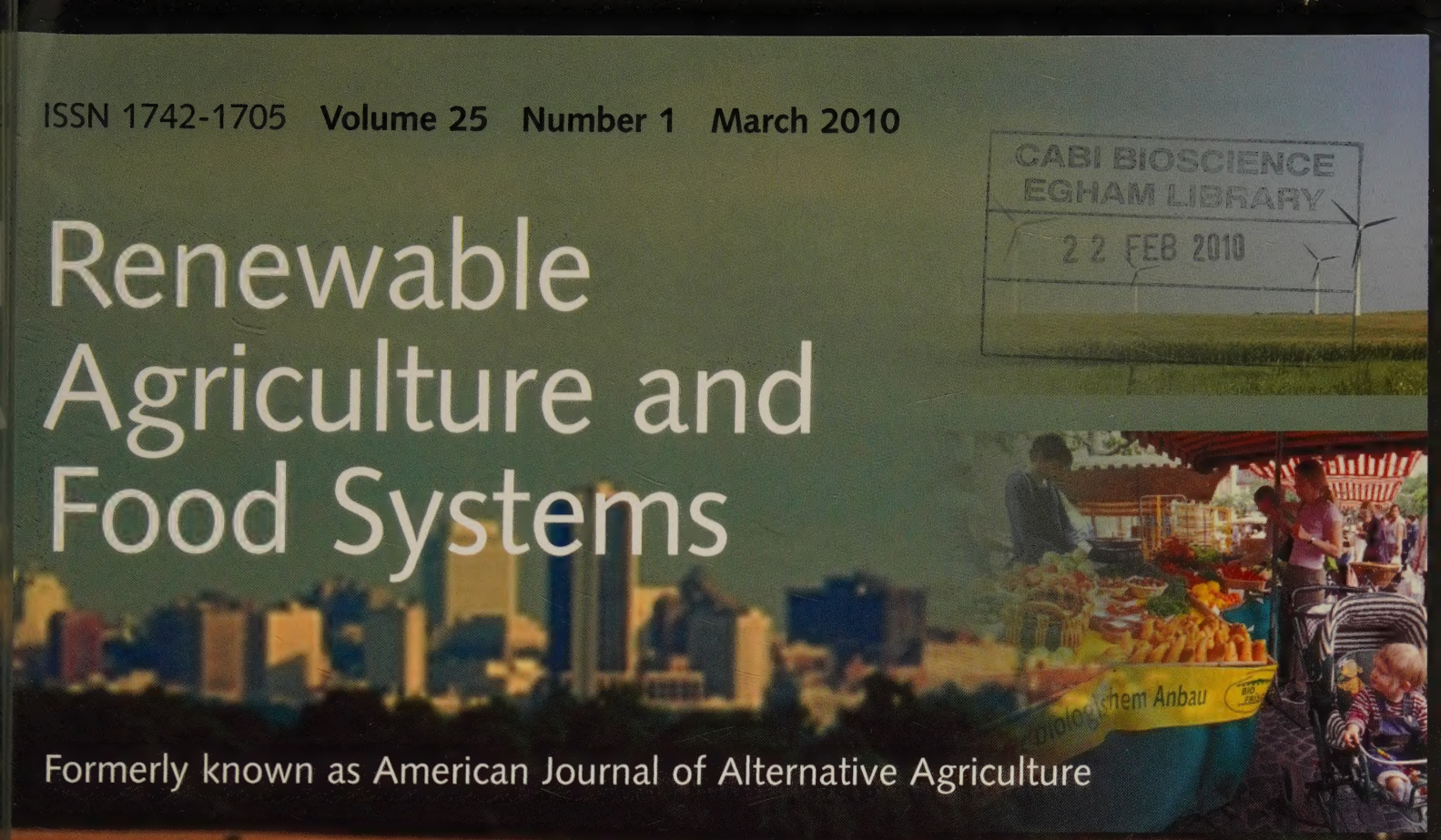

Special Issue

"Food for Life": Looking Beyond the Horizon
Charles Francis, John Doran, and the Editorial Team

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Renewable Agriculture and Food Systems

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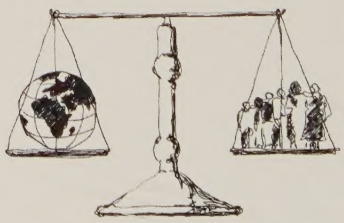

"Sustaining Earth and its People"

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Editorial: 'Food for Life': Looking beyond the horizon

The exciting challenges for a journal editorial team include attracting papers based on quality science, providing an efficient screening process, completing reviews and making decisions in a timely fashion, and producing a journal that will be internationally accepted, useful to readers and make a practical impact in the field. To accomplish this we depend on good management and a supportive publisher and staff. Success could be measured by the number of articles submitted, the rate of acceptance and of course the number of subscriptions and renewals. At present, these indicators are positive for *Renewable Agriculture and Food Systems*.

Yet the above indicators represent the minimum criteria for scientific and practical credibility. To be sure, a journal must report the results, analysis and interpretations of completed research, and in the case of *Renewable Agriculture and Food Systems* we also value the practical implications for development of enhanced and more sustainable farming and food systems. Too often we observe that research reported in our journal as well as in most others deals with production and economic challenges that are of the moment, and for which many answers have already been tested and discussed. In this way, we add to the storehouse of credible scientific knowledge, but will this research have an impact on the real needs of people, today and into the future? It is important to note that most research initiated today will not yield applicable results for at least 5 years—even longer in the case of plant breeding, crop rotations or soil quality. Our real challenge appears to be anticipating what the major challenges and constraints will be to food production and distribution a decade or more into the future. This could be called 'Beyond the Horizon' thinking.

To this end, the team of Associate Editors was asked to look down the road in the food system and to provide suggestions on where we are headed, what constraints will be important in the near- and medium-term future, and what the journal could do to focus more on emerging issues. A small group then met in Pittsburgh during the international meetings of the American Society of Agronomy in November 2009 to discuss and debate potential long-term strategies for the journal. Discussions were preceded by an e-mail calling for each Associate Editor's personal visions of how *Renewable Agriculture and Food Systems* serves to illuminate and further the task of renewing Earth and its people and the general vision of 'Food for Life'. Responses included recognition that achieving renewable agriculture and food systems is an international goal that must deal more with the socio-political challenges of meeting future food needs using scientific and ecologically based systems that enhance the environment and address critical issues such as climate change and diminishing resources.

In order to bring focus to the challenge, we found it essential to recognize the most likely and overriding constraints to future food production. Today there is little disagreement over the massive depletion on a global scale of two essential inputs to agriculture: fossil fuels and fresh water. We also recognize that phosphorus is found in concentrated form in only a few deposits in nature, and that agriculture is rapidly using this limited resource and dispersing it through harvested products and soil loss from fields in forms that make it economically unavailable for recycling. Less recognized is the increasing occurrence of severe weather events. As pointed out by Forum Editor Fred Kirschenmann, we are moving from two centuries of relatively benign climate that was highly conducive to stable agricultural yields to a time of more frequent droughts, floods and other potentially disruptive weather events. Are we effectively developing a food production system that will give resilience in the face of uncertainty and major fluctuations in natural conditions? Or do we see the future as a simple extrapolation of the past?

The editorial team strongly believes that we should create a journal that addresses these emerging realities and create a forum for logical discussion of how and why to choose achievable, resource-efficient farming systems. We can encourage new directions by establishing critical topic issues, such as a forthcoming special edition on *Sustainable Agricultural Systems in a Resource-Limited Future* edited by Welsh, Oberholtzer and Dimitri. Recognizing that agriculture and food represent a global challenge, the journal is attracting more articles from the international scientific community, beyond the borders of North America and the European Union, as reflected in the current issue of the journal. In addition to broadening our spatial focus, it is important to seek a more robust profile in transdisciplinary studies—often called multidisciplinary or interdisciplinary research—that embrace the production, economics, environmental and social dimensions of the food challenge. However, as stated by Eksvärd in this issue, 'moving from conventional research approaches to transdisciplinary approaches is not easy and includes the need to relate the contextual knowledge of farmers to the abstract knowledge of scientists'. To pursue this focus is to create a unique niche for *Renewable Agriculture and Food Systems*.

We welcome future submissions to the journal, covering topics that fulfill the overall goal of meeting future food demands in a changing global environment while making maximum use of locally available renewable resources. Integrative papers that look at complex production systems—multiple cropping, crop/animal systems, long-term rotations, permaculture and agroforestry—come to mind. Papers that deal with whole farm systems, as well

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as landscape-, community- and regional-level food systems will be valuable to those in planning and in resource allocation for investigation. Research that combines biological and social science methods has a better chance of addressing complex challenges and uncertainty, and especially those issues that include a strong component of human decision making. Important to us will be topics dealing with integrated approaches that balance needs for production with those for environmental stability such as conservation tillage in organic farming systems, biologically intensive agriculture and life-cycle analysis of nutrient use in agricultural systems to name a few. Political dimensions of agriculture and food systems are highly important, and in fact too critical to be left exclusively to the domain of economists, lawyers and politicians. Contrary to the conventional wisdom of most agricultural scientists, these are important researchable questions that should be pursued and the results published.

Among the characteristics that we consider likely to embody future agriculture, looking 'Beyond the Horizon' as a group, we consider it important to study and develop systems that:

- Depend largely on contemporary energy, current sunlight rather than scarce fossil fuels.
- Make highly efficient use of limited water supplies, saving expensive irrigation for production of high-value crops.
- Integrate crops and animals in ways that cycle and make efficient use of nutrients.
- Make efficient use of human urine and feces as well as those from domestic animals, an essential step in nutrient cycling for the future.
- Display biodiversity and resilience in the face of unpredictable and extreme weather events.
- Favor owner-operated and managed farms of a reasonable scale that contribute to local economies and food systems.
- Encourage beginning farmers, women entrepreneurs and minority groups to become more active in the commercial food system.
- Reflect the unique role of local people and groups in human-managed agroecosystems.
- Recognize the overriding importance of ecology and uniqueness of place in the design of agricultural systems.

Organic agriculture is one alternative that has grown rapidly over the past two decades. A valuable international history of organic production has been assembled by Dr William Lockeretz, former editor of *American Journal of Alternative Agriculture*, the forerunner to this journal (see book review, this issue). Two other books also appearing in the past year (Kirchmann and Bergström, 2008; Francis, 2009), as referenced in the above book review, provide contrasting views of the science and the future of organic farming and food systems and should be consulted along with the Lockeretz history to gain multiple perspectives on this growing, and at times controversial, option for the future. It is this type of issue that *Renewable Agriculture and Food Systems* needs to address through solid science and through commentary articles by readers. We also recognize the often futile results of research dealing with controversial topics (see Francis commentary, this issue), although discussing controversies is essential to address the larger challenges and myths that abound in our profession when we have the appropriate methods and statistical analyses needed to reach convincing conclusions.

These are some of the directions that appear important to our editorial team. We must find ways to deal effectively with the future, and to shape systems to meet human needs across the economic spectrum and around the globe. Those solutions that benefit only a few in society do not provide stability or sustainability, nor do they create an equitable and desirable future. As always, the editorial team invites ideas from our authors and readers, and we especially welcome topics for special issues in the future as well as recommendations and volunteers to be guest editors for an issue of *Renewable Agriculture and Food Systems*. Above all, we invite you to join us in this quest to develop productive, dynamic, biodiverse, flexible, renewable and sustainable farming and food systems for the long-term future.

The Editor-in-Chief would like to extend thanks to the many reviewers who provided timely, substantive and insightful reviews for *Renewable Agriculture and Food Systems* in 2009. Your efforts and those of our Associate Editors have resulted in a quality journal that enables the online publication ahead of issue printing within 4 to 6 weeks of individual manuscript acceptance and an average of 90 days from submission to decision. Gratitude is also extended to the journal support staff of Cambridge University Press for outstanding management of the editing, production and marketing of the journal. An easily recognized indication of the journal's advancement is the rise of the Impact Factor between 2005 and 2009 from 0.3 to 0.9.

A special welcome to Jacqueline Clark who joined the *Renewable Agriculture and Food Systems* team as Editorial Assistant, with a background in Sustainable Development, and to John Beeby from Cornell University who joined the Associate Editor's Board this past year. Thanks are extended to Richard Auler, Ladybird Organic Farm, Co. Tipperary, Ireland who retired from the Editorial Board in 2009.

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Conventional research on controversial issues: an exercise in futility?

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Accepted 17 November 2009; First published online 22 December 2009 **Commentary**

Abstract

Results from research on controversial topics are often interpreted according to the world view of the reader. With conflicting results from different researchers or institutions, it is likely that vested financial interests or adherence to conventional wisdom will lead to rejection of science-based conclusions. An example from the past is the comparison of multiple cropping with monocrop systems, where clear advantages of complex systems are discounted by those committed to the monoculture paradigm. A current example is comparison of organic with conventional farming systems and food products, where food price, suspicion about certification and philosophy about perceived 'non-scientific' results cloud the technical conclusions. An emerging example is comparisons of local versus global food systems, where multiple issues including comparative advantage and food preferences obscure the key questions of energy investment, food equity and local well-being. A proposed solution to this dilemma is to instead focus scarce research funds on improving the development of alternative agroecosystems, rather than invest human energy into futile comparisons that are unlikely to convince the skeptics. In this way, more creative alternatives can be explored and greater progress made toward food equity and sufficiency.

Key words: multiple cropping, organic farming, organic food, local food systems, globalization, research priorities

Introduction

Scientists are often frustrated when their hard-earned results are not accepted by the public. An example is the continuing public controversy and lingering debate about global warming. When scientific results are contrary to the vested business interests of powerful companies, it may take decades for society to take decisive action. Such historical frustrations abound. The astronomer Galileo discounted the popular geocentric view of the universe and was indicted for this discovery. Columbus was certain to be sailing off the edge of a flat Earth according to the wine shop discussions of the day. Contemporary challenges to Darwin's work on evolution come from those who find conflict with their biblical interpretations. These scientists and innovators surely felt their efforts were futile in the face of dominant opinions in society.

Thomas Kuhn[1] described the strong adherence to current paradigms in his landmark book, *The Structure of Scientific Revolutions*. A small sector of the society finds it difficult to change public opinion—despite the evidence. Examples of resistance to change abound in agriculture, as illustrated by the relatively slow adoption of hybrid maize or the lag time between introduction of no-till planting in the Great Plains and wide farmer acceptance of the practice. *Silent Spring*, Rachel Carson's[2] critical expose of the negative impacts of pesticides, created wide controversy about chemical use. In spite of convincing scientific evidence, change away from current practice is slow to happen—due to inertia, aversion to risk, or financial and intellectual investment in the present paradigm.

Three examples in agriculture and food systems can illustrate the difficulties of major change, and perhaps demonstrate our need to pursue a different strategy in research on controversial topics. A *topic from the past* is tropical research on intercropping, where improved versions of traditional systems were often compared to monocultures, and results rarely changed anyone's mind about the potential of multiple cropping for future food production. A *topic in the present* is the comparison of organic and conventional cropping systems, where results are interpreted based on people's underlying values and

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philosophies rather than on the experimental results derived using the scientific method. An emerging *topic for future research* concerns the rapidly globalizing food system and local food options, where it is likely results will not convince critics of either system that alternatives have an important role to play in tomorrow's food environment.

There has been exhaustive research on the first two questions and enthusiasm with emerging research around the third. Results showing that multiple cropping has an important role for the future, or that organic cropping systems can be productive and more profitable than conventional systems, are not convincing to those who have invested heavily in the dominant monoculture and industrial agriculture paradigms. Opinions may be based on strong conventional wisdom, or on a large financial involvement potential threatened by alternatives.

What has science contributed to resolve the controversies listed above? What evidence suggests we pursue different research priorities for the long term? Finally, how do we use science to effect meaningful change in the face of controversial challenges? After discussion of the evolving foundations of science, three case studies of research on controversial issues are presented, along with conclusions and recommendations for future research priorities. A research strategy is proposed that investigators (1) carefully consider the context in which results will be applied, (2) be explicit about specific assumptions on future availability of resources and (3) emphasize the newly emerging systems, without spending inordinate time and resources on comparisons. It is proposed that this is a valuable strategy for improving food and farming systems.

Evolving Foundations in Science

Most scientists in agriculture were educated, or more likely trained, in the contemporary model of discipline-bound science: agronomy, soils, entomology, animal science and agricultural economics. There have been limited opportunities to consider holistic strategies that depart from reductionist orthodoxy to explain the world through science. For those few fortunate to have taken a course in history of science or for other reasons to have challenged the dominant mechanistic paradigm of 'hard science', it is a small step to embrace a wider vision of how the scientific method can be applied to current questions that involve environmental and social dimensions in addition to production and economics. Agroecology, defined as *the ecology of food systems*[3], covers this broad approach.

In *The Web of Life—a New Scientific Understanding of Living Systems*, physicist Fritzof Capra[4] documents the historical 'tension between mechanism and holism ... as an inevitable consequence of the ancient dichotomy between substance (matter, structure, quantity) and form (pattern, order, quality)'. He further describes how Aristotle 'distinguished between matter and form but at the same time linked the two through a process of development'. In chapter 2, From the Parts to the Whole, Capra[4] details the radical changes that challenged Aristotle's concept of wholeness. The mechanistic and reductionist foundation of the Scientific Revolution grew from the brilliant work of Galileo Galilei, René Descartes, Isaac Newton and others in an array of technical fields. From cell theory to embryology and microbiology, then to understanding heredity, the belief prevailed that systems would be explained by aggregating their components. Although the effects of environment were recognized and quantified, the search to explain mechanisms was relatively devoid of context. Assumptions were that the future would resemble the past in most ways, especially in dogma of science. Early proponents of alternative thinking included Sir Albert Howard and Lady Evelyn Balfour in the UK, among others. It was only with the emergence of ecology and systems thinking, and such creative advances as the Gaia hypothesis[5], that serious challenges to mechanistic thinking began.

In dealing with broad and complex issues, research results are rarely conclusive and often inadequate to convince anyone who has invested in the opposing paradigm. Three case studies are presented that represent controversial issues in the food system and the argument is made for intensive research on the emerging alternatives. There is no question about the need for research on controversial issues, but in the context of global food needs and growing negative impacts of agriculture it is important to seek near-term and creative answers.

Multiple Cropping Systems versus Monoculture

Agriculture began with mixtures of species, as early farmers emulated the natural biodiversity, and then gradually selected individual plants and plant species that most suited their food needs. Early small grain mixtures in northern Europe gave way to cereal monocultures that were predecessors to our current systems in the US Midwest. Maize/bean/squash systems in Central America were replaced by monocultures on favored lands well suited for mechanized technology. Yet complex systems persisted where farmers had limited land resources and limited access to fertilizers and pesticides. Some researchers in the 1970s began to explore the potentials of multiple cropping systems[6].

Most multiple cropping researchers were trained in reductionist science and began to look at components of systems. Research at the *Centro Internacional de Agricultura Tropical* (CIAT) in Colombia focused on maize and bean genotypes for intercropping, relative densities and planting dates, and physical orientation of different maize and bean combinations[7,8]. Important to these breeding programs was the study of genotype by system interactions, since unique adaptation of intercropping would signal the need for separate breeding or at least testing programs in complex systems[9].

Prevalent thinking during these evaluations emphasized comparisons of intercrop and monocrop system

performance. The multiple crop system often 'overyielded' monocultures, measured by the Land Equivalent Ratio (LER)[10] or Area-Time Equivalent Ratio (ATER)[11]—which compare total crop yield of mixtures with the yields of monocultures of the component species. Net incomes from the two systems showed greater returns to intercrops, and this could be considered a more integrative and valuable measure of performance to the farmer[12].

In a quest for technical credibility, peer acceptance and convincing evidence that multiple cropping systems indeed were at least equal to conventional monocultures, scientists included single crop 'check plots' for comparisons. This allowed calculation of the land efficiency indicators described above. Discoveries of LER values greater than 1.0 only confirmed the conventional wisdom of those doing the research that multiple cropping systems had great potential for the future. These same results did little to persuade people committed to the monoculture paradigm to seriously consider alternatives, because they focused on such complications as harvesting crops growing together, or because the alternative system did not stir their vision of future agriculture. Another shortcoming of early multiple cropping research on component technologies was the narrow focus on production and economics, with little or no attention to environmental or social implications of the systems. From today's perspective, we conclude that much of this research on a controversial topic did little to change the direction of mainstream research, nor to influence regulations or farm supports to encourage more production in complex systems. Some practical recommendations for farmers emerged, but much of the replicated field work for publishing results could be called 'agronomic trivial pursuit'.

Organic versus Conventional Farming and Foods

Over the past two decades greater attention has been focused on alternative farming systems. Demand for organic food has grown for reasons associated with food safety, nutrition, environmental quality and social justice. In 2006, there were over 30 million ha managed organically, and global sales of organic foods were near US$30 billion[13]. A number of scientists have compared systems' productivity and food quality of products between the two systems and results have been mixed.

Comparisons of organic and conventional production systems have been conducted by two groups, each considering their approach objective. Some conventional researchers, who would like to prove that organic systems have little to offer, merely cut out chemical weed control and/or fertilizer application, and as expected, the organic systems yields are much lower. There are limited numbers of these experiments today, yet they are used to support the contention that organic farming cannot feed the world or that much more marginal land would be required for production to meet global food demand, increasing the negative impacts of farming on the environment[14]. Perceptive scientists do not take these studies seriously.

Research frequently is conducted on components of systems—weed management methods, sources of nutrients to maintain soil fertility, timing of cultural practices and comparisons of alternative crops. As with conventional industrial agriculture, there is continuous search for a magic bullet, a productive system that will fit in many field niches, one that allows simplicity in management by providing the correct menu for varieties, fertility, weed control and other practices. Most research including organic is directed at improving efficiency of current systems or substituting one input for another, the first two steps in the complexity hierarchy described by MacRae et al.[15]. There is little research that looks at redesign of the whole system.

The first challenge is identifying the most important components that should be changed to create an organic system that will outperform—agronomically or economically—a nearby conventional system. Conventional statistics are valuable to conduct comparisons on one- to three-factor experiments, yet less valuable in comparing whole systems that differ in a larger number of components. Often intent on ferreting out the effects of individual components, even though these are completely confounded in the large systems comparisons, frustration mounts when scientists try to explain why one system is superior to another. Complicating the comparisons are the relatively singular goals of conventional systems—production and economics, while the multiple economic, environmental and social goals of farmers using organic systems require a wider suite of indicators. These complexities add to the difficulty of designing, analyzing and interpreting results of systems comparisons.

Results of conventional and organic systems research are open to wide interpretations, often clouded by the assumptions of the researchers and those who read the results. Interpretations are further confused by conflicting world views of scientists, differences between authors and reviewers, priorities of researchers and administrators and perceived utility by clients. Consequences may be more confusion, less communication and lost opportunity cost of improving an emerging alternative system called organic farming.

Local versus Global Food Systems

The emergence of local food production as an alternative to food produced from a globalized industrial system has generated significant recent debate[16]. Many of us enjoy coffee every morning and would find it hard to abandon the banana with our granola. We participate in a global food system that assures we can buy that banana any day of the year in food markets of any size. Observing the produce section in most US food markets reveals apples from New Zealand, kiwi and grapes from Chile and oranges from Mexico. In markets in the Midwest and the eastern

two-thirds of the US we find lettuce, broccoli and other vegetables from the west coast, even during the season when local production is possible. For half a century, foods have moved widely into and across the US, but only recently have we begun to seriously calculate the impacts of this massive transportation complex[16,17].

Economic and climatic factors compel us to specialize fresh fruit and vegetable production at sites where a comparative advantage of favorable climate, adequate labor and available transportation make this system profitable. For example, tomatoes can be grown in glass house facilities in southern British Columbia, but the energy cost is 17 times higher than producing the same tomatoes in the field[17]. The average food travel distance required to put a meal on a dinner plate in Iowa is currently about 2500 km[16]. Although fluctuations in price of fossil fuels will change the food transportation equation on an almost daily basis, there is no doubt that there will be adjustments toward more local foods in the near future.

In typical reductionist research thinking, we focus on one pet indicator ... whether this is food kilometers, comparative climatic production advantage of different locations, large differences in labor costs, specialization versus diversity in local production systems, or local food security. Serious evaluation of global versus local requires attention to all these factors and many more.

New questions emerge from these studies. What is the impact of outsourcing a high percent of food production to other countries in a world with volatile petroleum prices, differing food safety standards and levels of enforcement, and political instability? What about equity and access to food by local people in countries where these prime products are grown for export? To what extent do the financial benefits of food exportation trickle down to the poor who are hungry? The poorest people, who often live in rural areas and are involved in food production, may be those who suffer most. Food is recognized as a basic human right in the International Declaration of Human Rights by the UN, but this has gone virtually unheeded for six decades. With the publication of the Bruntland Report, *Our Common Future*[18] attention was once again drawn to the tragedy of undernutrition in many countries.

How do we objectively compare local with global food systems, and what impact would the results of such research have on people's food decisions and on government food policies? It would be highly relevant to look at the whole food system from capture and use of natural resources through the farm production process to processing, marketing and consumption, as well as to the disposal or recycling of non-consumed waste. Life-cycle accounting has become commonplace in evaluation of production efficiency in a number of industries. Such evaluation often includes materials and economic indices, and should incorporate environmental impacts of alternative systems at each step of the process. Often neglected in such analyses are the social impacts and long-term implications of different systems, including the distribution of benefits. Although this becomes nearly impossible to calculate for individual food items, much less for entire food systems, appreciation of the fact that there are social dimensions that should be taken into account is a great step forward. If these analyses are carefully and thoughtfully done, it will be possible to get some idea of the relative costs and efficiencies of local foods versus those from a global industry.

How is such information used and does it have an impact? Proponents of local foods point to problems in today's global system, such as food kilometers, insecurity of long supply lines, lax environmental regulations and perhaps use of pesticides banned in the US and poor treatment of labor. Those invested in the global system will point to its advantages in efficiency of scale, appropriateness of growing food where the crops or animals are most adapted and labor is least expensive, and benefits of having a highly diverse food supply available every day of the year. Both groups would probably use some of the same research data to support their conclusions. Neither would acquire the convincing evidence to impact national policies, nor would they likely influence all but the most concerned consumers. Most food decisions appear to be made in the US based on price, on appearance, and perhaps on nutritional quality from the label or previous experience. Few people really care where the food came from or how it was produced. Thus, the research turns out to be interesting, perhaps publishable, but another exercise in academic trivial pursuit.

There is little doubt that tomorrow's food systems will combine local and imported food. The debate about what is considered local will continue. Is there a role for research to inform the debate, to educate the consumer and to influence policy? One strategy is to forego the research comparisons of local versus global foods, and concentrate on improving local food alternatives. Promoting diverse systems and appropriate practices that allow farmers to grow more foods for local consumers is part of this strategy. Education on the costs and implications of imported foods, when there are local options of foods in season, is another part of the puzzle. Supporting local farmers adds to the local economy.

How do we bring this information together through credible analysis in the current economic context to decide what type of balance is in the best interest for all people in the food system? It is unlikely that conventional component research approaches, and even larger system-wide analysis of alternative food systems, will provide clear answers. We need holistic methods for addressing these complex issues, yet the impacts of research may still be less than convincing.

Conclusions

From this discussion of three cases in agricultural research—multiple cropping systems versus monoculture, organic versus conventional farming and food, and local

versus global food systems—it is clear that research on complex issues is difficult. We have the experiment designs and statistical procedures that work well with single- and two-factor issues in agriculture, but less confidence in how to analyze the results of whole systems—on the farm, in a region, or at the national level. When most changes in cropping systems or food systems are made by adjusting or changing single components, one at a time, the confounded results of systems research make it difficult to pinpoint where to tweak the system. Thus our scientific methods appear to be less than adequate to answer large questions. This is especially notable when factors related to environmental sustainability or social impacts of research are involved.

What can we do to improve the relevance of research on difficult topics? Or should we spend scarce research funds on projects that will not lead to change? Recommendations for research on controversial topics may be summarized as follows:

- Research goals should be clearly defined, with specific hypotheses and methods or focus on a practical question to be explored.
- Scope of inquiry, including spatial context and time frame, need to be carefully thought out and articulated, with no intent to extend results beyond the frame of reference.
- Assumptions about the future are essential, especially with regard to natural resources, human population and vital need for ecosystem services.
- Expectations should not be too high, with regard to the publication or widespread use of results, since these are also likely to be controversial.
- Broad scope of reference should be used when appropriate, to include production, economics, environment and social impacts of research results.

Even more critical in the decision to work on controversial issues is to anticipate whether research will have an impact on the farming or food systems, on local or national policy, or on human well being. When there are production, economic, environmental and social questions all coming to bear on farmer decisions as well as on those made by others in the food web, the results of research can be ambiguous at best. Often the data can be used to support just about any side of complex arguments. In the study of controversial alternatives, one option is to thoughtfully invest available research funds on innovative new directions, build alliances with other groups that will help finance research as well as diffuse results, and trust in economics and an educated public to sort out complexity and make rational decisions. Such a strategy would be preferable to wasting inordinate time and energy doing comparison-type research that will not provide convincing results.

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Physical weed control in protected leaf-beet in central Italy

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Abstract

Leaf-beet is a typical and very important protected cultivation crop in central Italy. In leaf-beet protected cultivation, weed control is one of the most important problems because of its fairly long crop cycle (approximately 4–5 months). The aim of this research was to set up an efficient non chemical weed control strategy performed with innovative machines built and set up by the University of Pisa. A two-year (2006–2007) 'on-farm' experimental trial was carried out in Crespina (PI). A conventional weed management technique (consisting of one pre-transplanting chemical treatment) was compared with an innovative physical weed control strategy in an organic production system (consisting of using a stale seedbed technique, in several post-emergence precision hoeing and in-row hand-weeding treatments). In the conventional technique, leaf-beet was manually transplanted, while it was sown with a precision pneumatic planter in the organic system. All innovative machines for physical weed control were adjusted and set up for the protected cultivation. Similar yields were recorded for the two systems in this two-year trial. Total labor time (for weed management and crop planting) was appreciably lower in the conventional system in the first year of the experiment (−67%), while in the second year, some improvement in the physical weed control techniques decreased labor needs with respect to the conventional technique (−40%). Weed dry biomass at harvest was significantly lower in the organic cropping system (on average −50%).

Key words: organic farming system, machines for physical weed control, rolling harrow, precision hoe, flaming machine

Introduction

Integrated pest management and organic vegetable production systems have gained a great deal of attention in agreement with EU agricultural policy reorientations[1,2]; furthermore, this is in line with mounting public concern over environmental issues, work safety and the growing consumer demand for high-quality food products. One of the major technical problems that arise in vegetable production when decreasing the use of agrochemicals is weed control[3,4]. This is a very important problem in protected cultivation in which an inevitable intensification of cultivation leads to even more difficulties. Protected cultivation has many commercial advantages but it has many agronomic and crop protection problems, including weed control. This problem, which is very important for horticultural crops, can be tackled and solved in a sustainable way by using and optimizing physical weed control.

Recently, a series of techniques and purpose-designed operative machines have been devised to perform efficient and economically viable non chemical weed control in open fields. Numerous interesting trials have been carried out with promising results on spring–summer crops[5–12], on winter cereals[13–16] and on horticultural crops[17–35].

In contrast, research on physical weed control in protected cultivations has not been conducted to the same extent. For this reason, technical and scientific knowledge available on this topic is lacking. Moreover, field techniques and machinery cannot be directly applied to different crops and operative conditions. Therefore, to develop a sustainable weed control in protected cultivation, it is necessary to develop or adapt machines to be used under different operative conditions and to determine the interactions among operative parameters (crop typology and management practices, as well as weed density, developmental stage and competitiveness, soil conditions, protection typology, etc.)[3,12,22,29,36–41].

An experiment was carried out on leaf-beet [*Beta vulgaris* L. var. *cycla* (L.) Ulrich] in order to develop and assess strategies to decrease or eliminate herbicide use in

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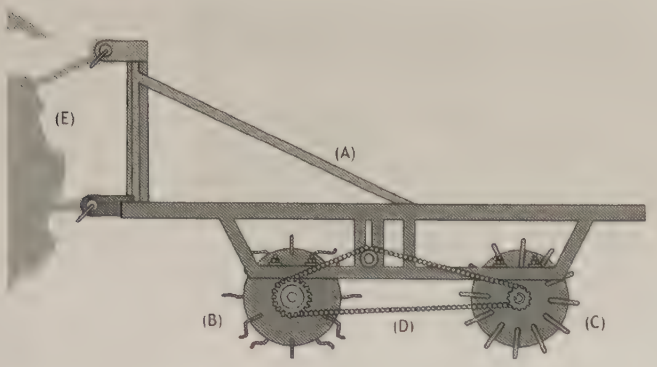

Figure 1. Schematic drawing of the rolling harrow: (A) frame; (B) front axle with spike discs; (C) rear axle with cage rolls; (D) chain drive and (E) three-point hitch.

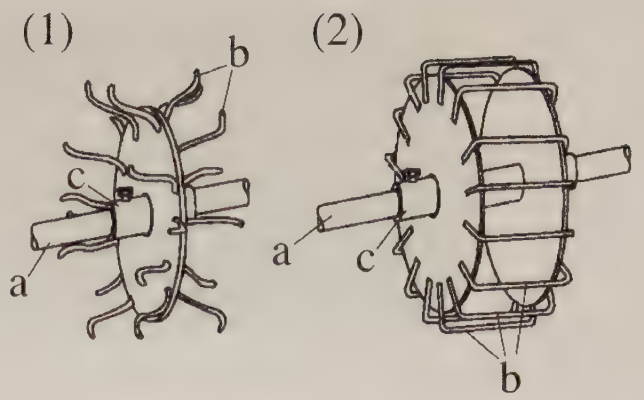

Figure 2. Schematic drawing of the working tools of the rolling harrow: (1) spike disc; (2) cage roll: (a) rotating axle; (b) spikes and cages and (c) sliding locking device of the units.

protected cultivation. In Central Italy, leaf-beet is a major crop under protected cultivation. It has a long crop cycle (between 4 and 5 months) and consequently weed control is one of its most important problems. In the experimental trials, a conventional weed management technique was compared with innovative physical weed control strategies.

Materials and Methods

A two-year (2006–2007) 'on-farm' experiment was carried out in Crespina (PI). The experiment was carried out on farms close to each other, conventional and organic, with similar sandy soil (sand 67%, silt 26%, clay 7% and organic matter 2%) and climatic conditions. Trials were performed in two 100 m × 7 m non heated greenhouses (2.25 m high).

On the organic farm, sowing was performed with a precision planter in August. The seeding rate was 30 seeds m^{-2} (20 × 12 cm) on ridges 1.4 m wide (with 5 rows $ridge^{-1}$). On the conventional farm, leaf-beet was first seeded in seedbeds in August and manually transplanted in the greenhouse or tunnel at the end of September at a rate of 12 plants m^{-2} on ridges 1 m wide (with 3 rows $ridge^{-1}$).

First year

The non chemical weed control strategy was carried out by using the false seedbed technique (with the rolling harrow), three post-emergence precision hoeing and two in-row hand-weeding treatments performed between hoeing treatments.

The conventional weed control strategy was carried out by transplanting and using one pre-planting chemical treatment (8 kg ha^{-1} Kerb, a.i. propizamide).

The physical weed control machines were studied, built and set up in this experiment by the Research Unit to perform effective and efficient treatments.

The rolling harrow was developed to perform a very shallow tillage and to provide effective weed control both in 'false seedbed' technique and in precision hoeing treatments after crop emergence. The machine is modular, so it can be built with different working widths adapted to row spacing (Fig. 1). Furthermore, the rolling harrow is structured on a square frame bearing working tools and three-point linkage. The tools are spike discs with a diameter of 30–35 cm (placed in the front) and gage rolls with a diameter of 27–33 cm (placed in the rear), which are inserted on two axles, connected by means of a chain drive with an easily adjustable ratio (Fig. 2). Discs and rolls of different sizes can be interchanged with a very simple blocking system. The discs and the rolls can be placed differently on the axles (Fig. 3): close together in order to perform a very shallow tillage (3–4 cm) of the whole area for seedbed preparation and non selective mechanical weed control (stale seedbed technique) and with spaced arrangement to perform selective mechanical weed control treatments post-emergence precision inter row weeding. In precision weeding, it is possible to work on a range of inter row widths from a minimum value of 15 cm. The action of the rotating rolls harrow is characterized by the passage of the spike discs that till the soil at a depth of 3–4 cm followed by the passage of the gage rolls that work at high peripheral speed as the rear axle is powered by the front axle by means of an overdrive, tilling and crumbling the soil to a depth of 1–2 cm. The rolling harrow can be equipped with couples of elastic tines (working as both vibrating teeth and torsion weeders) in order to also perform a mechanical weed control in the rows (Fig. 4). For precision weeding, a version of the rolling harrow with a steering handle system was set up. In these trials, a machine 1.4 m wide was used.

The precision hoe used in this experiment is a 2 m wide machine (Fig. 5), designed to perform selective weed control in the row crop with very narrow inter-row distances (in this trial 20 cm). The precision hoe is structured on a square tool bar bearing working tools and attached to the three points. There can be up to 11 working tools and each is placed on an articulated parallelogram equipped with a small wheel for adjusting working width. The machine was equipped with rigid elements bearing a 9 cm wide triangular horizontal blade and two kinds of flexible tines (torsion weeders and vibrating tines). The tines

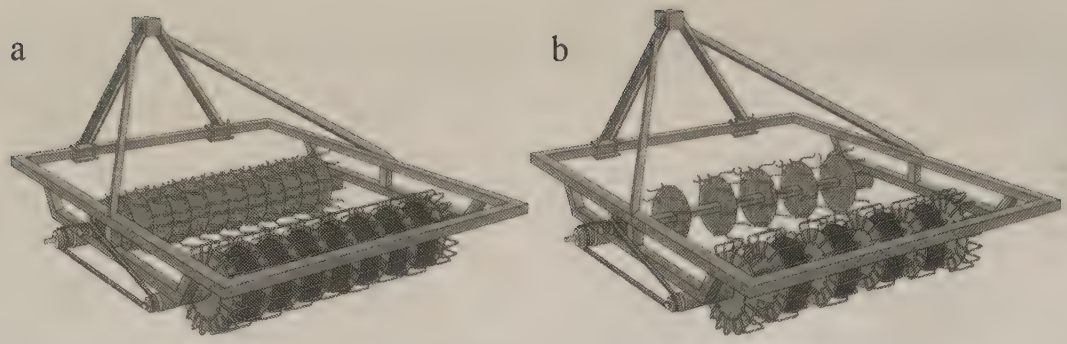

Figure 3. Arrangement of the rolling harrow to carry out treatments on whole surface (a) and of hoeing (b).

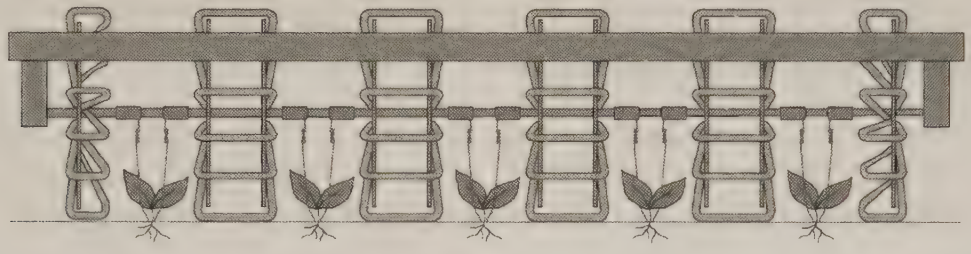

Figure 4. Schematic drawing of the combination of the rolling harrow with flexible tines, in order to carry out selective treatments both between and in the rows.

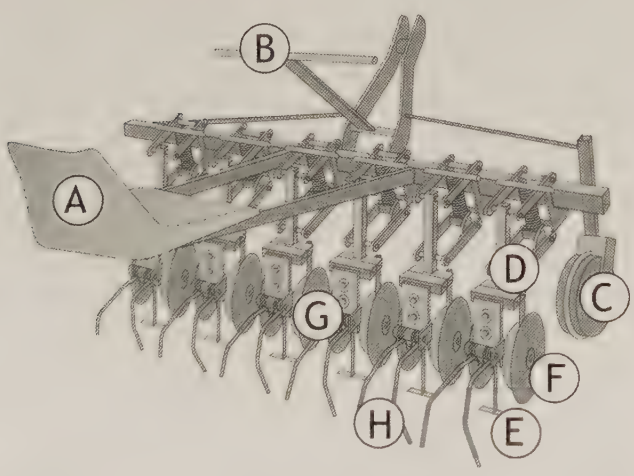

Figure 5. (A) Hoe operator seat; (B) steering handle; (C) steering wheel; (D) articulated parallelogram; (E) working tool; (F) lateral disc; (G) support wheel and (H) elastic tines.

perform selective weed control on the row crop (Fig. 6). A back-seated operator can adjust the actual position of the working tools with a steering handle. This precision hoe is a very interesting innovation for farms because it is able to work on five rows on a 'standard' ridge 1.4 m wide.

On the conventional farm, a Project srl sprayer was used for chemical weed control, with a tank capacity of 300 dm^3. The treatments were performed with a hand lance equipped with a turbulence full cone spray nozzle and with a manual valve for flow adjustment. The hand lance was equipped with a 100 m long hose (Fig. 7).

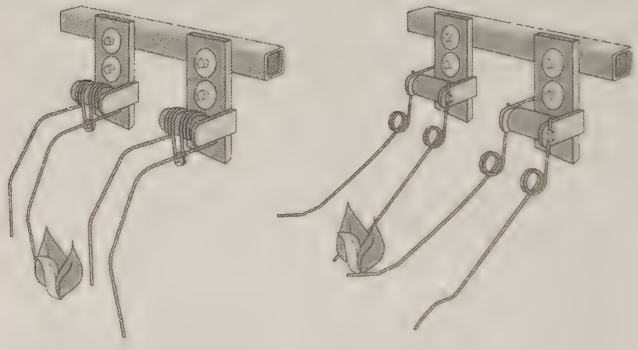

Figure 6. Vibrating tines (left) and torsion weeders (right).

Second year

On the conventional farm, the crop was transplanted and weed control consisted of applying an herbicide prior to transplanting (3.5 kg ha^{-1} Betanal, a.i. phenmediphan). The application was done with the same machine as the one that was used the previous year.

On the organic farm, in light of the first year results, weed control was carried out with a modified strategy performed using the false seedbed technique (by a rolling harrow), one flaming pre-emergence of the crop, two post-emergence hoeing (the first with the rolling harrow, the second with the precision hoe) and one final in-row hand-weeding treatment. For physical weed control, besides the machines used in the first year, a flaming weeder constructed by the research team was used.

Figure 7. Sprayer utilized for chemical treatments.

The flame weeding implement can be used both pre-emergence (nonselective) and post-emergence (selective) (Figs. 8 and 9). The flaming machine can be equipped with up to eight rod burners that are 25 cm wide with a good flame shape and with four LPG tanks. Pairs of burners are placed on a control board and connected to a 25 kg LPG tank on which a pressure regulator and a manometer are placed. The LPG tanks are placed inside a hopper, which contains warm water, thus allowing a good exchange of heat. The exhaust gas of the tractor engine is used to heat the water through a hose connected to both the exhaust head and a copper tube placed inside the hopper. Pairs of burners are connected to an articulated parallelogram in order to maintain the set out adjustments (height and inclination with respect to soil surface) when the flamer is working. Each burner is also equipped with one valve, one safety tap and an electronic control system that allows the tractor driver to adjust the LPG feed (high or low levels) and to control the functioning of the burners directly from his seat.

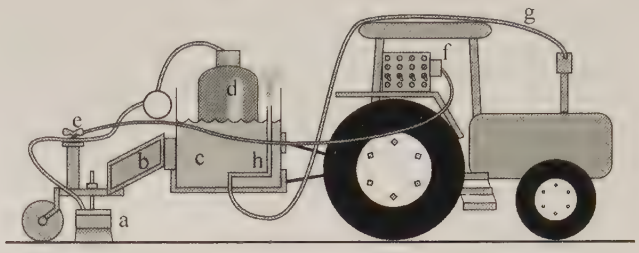

Figure 8. Schematic drawing of the new flaming machine: (a) burner; (b) articulated parallelogram; (c) hopper containing water; (d) LPG tank; (e) shelf on which the inflow LPG control system is located; (f) control panel; (g) flexible pipe that pipes the exhausted gas of the tractor engine to the heat exchanger in the hopper and (h) heat exchanger.

Experimental assessments

Trials were carried out on the entire surface of greenhouses, each of them was split into three different 30 m × 7 m plots (replications), along the longest side.

During the trials, data concerning machine and yard operative characteristics, weeds and crop yield were measured or calculated.

Machine and yard operative characteristics. During the experiment, all the main operative characteristics concerning weed management for both farming systems were registered and computed: working depth, working speed, working productivity, working time, fuel and LPG consumption for all the machinery used for weed control; manpower requirements for all manual weeding interventions.

Weeds. Weed density was recorded before and after each physical weed control treatment performed within the organic farming system and before the herbicide treatment in the conventional system. In this regard, a species-specific weed count assessment was performed on three 0.25 m × 0.30 m sampling areas plot^{-1}. At harvest, for both weed control strategies, weed samples were collected from two 1.5 m^2 areas plot^{-1}. Samples were then oven dried until constant weight in order to assess dry biomass of weeds. During the second year, an additional weed sampling was carried out at harvest by means of the Braun–Blanquet ordinal scale in order to assess weed canopy, biodiversity and aggressiveness.

Crop yield. Crop yield was sampled from the end of November to the end of February, at 10–15 day intervals, from two 1.5 m^2 areas plot^{-1} in order to evaluate total fresh leaf production.

Statistical analysis. Weed and yield data were analyzed statistically. Each strategy was tested in one greenhouse, without randomization, because it was not possible and not experimentally correct to perform chemical treatments on organic farms and to grow organic leaf-beet on conventional farms. Thus, the two different farming systems were compared using a two-tailed *t*-test. The statistical analysis was carried out using Systat version 11[42].

Results and Discussion

Operation characteristics

The characteristics of the machines used in the first year trial are presented in Table 1.

The rolling harrow, utilized only for pre-sowing treatment, was used at a high speed (approximately 6 km h^{-1})

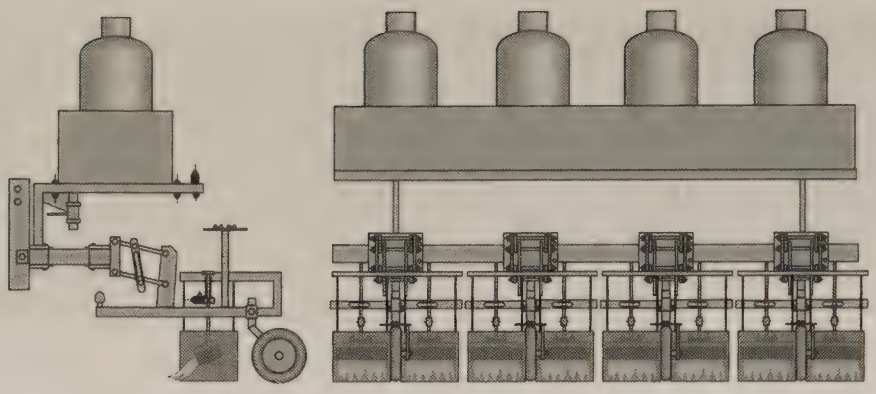

Figure 9. Side and rear view of the flaming machine in configuration for pre-emergence treatments.

Table 1. Performance of the machines used for physical weed control in the organic production system in the first year.

Characteristics	Har	Hoe 1	Hoe 2	Hoe 3
Working width (m)	1.35	1.35	1.35	1.35
Working depth (cm)	3.6	2.6	2.7	2.8
Working speed (km h^{-1})	5.9	1.2	1.1	1.2
Working productivity (ha h^{-1})	0.68	0.16	0.15	0.16
Working time (h ha^{-1})	1.47	6.21	6.87	6.36
Operators	1	2	2	2
Tractor engine capacity (kW)	37	37	37	37
Fuel consumption (kg ha^{-1})	2.9	12.4	13.7	12.7

Har, harrowing; hoe, hoeing (1, 2, 3, first, second or third pass).

Table 2. Working time for physical weed control in the organic production system in the first year.

Working time	
Physical weed control (h ha^{-1})	21
Sowing (h ha^{-1})	4
Hand weeding (h ha^{-1})	259
Total (h ha^{-1})	284

Table 3. Characteristics and working time in the conventional production system in the first year.

Characteristics	
Transplanting time (h ha^{-1})	84
Spraying time (h ha^{-1})	8
Total (h ha^{-1})	92
Working productivity (ha h^{-1})	0.13
Sprayed mixture (l ha^{-1})	2817

Table 4. Performance of the machines used for physical weed control in the organic production system in the second year.

Characteristics	Har	Fla	Har	Hoe
Working width (m)	1.35	1.35	1.35	1.35
Working depth (cm)	3.5	–	2.7	2.8
Working speed (km h^{-1})	6.1	3.5	1.7	3.0
Working productivity (ha h^{-1})	0.73	0.42	0.22	0.37
Working time (h ha^{-1})	1.36	2.39	4.47	2.71
Operators	1	1	1	2
Tractor engine capacity (kW)	37	37	37	37
Fuel consumption (kg ha^{-1})	2.7	4.8	8.9	5.4

Har, harrowing; Fla, flaming; hoe, hoeing.

and therefore its working time was low (1.47 h ha^{-1}). The precision hoe was used with a working speed of 1.2 km h^{-1} and consequently the working time for each treatment was approximately 6 h ha^{-1}. The working depth was lower than 0.04 m for all treatments. Fuel consumption was approximately 3 kg ha^{-1} for the false seedbed treatment and 13 kg ha^{-1} for each hoeing.

Total working time for physical weed control (Table 2) was roughly 280 h ha^{-1}. Most of this time was due to the two hand weeding operations, over 80 and 170 h ha^{-1} for the first and second weeding, respectively.

In a conventional strategy for weed control (Table 3), the time for manual transplanting (a technique that facilitates the crop rather than the weeds) was approximately 85 h ha^{-1}, while working time for chemical treatment was roughly 8 h ha^{-1}.

In the first year of the project, the physical weed control strategy required a total labor input higher than the conventional strategy (284 versus 92 h ha^{-1}, respectively).

The operation characteristics of the machines used for physical weed control in the second year trial are presented in Table 4.

For the false seedbed treatment, the rolling harrow worked at a very high speed and consequently its working time was short (1.36 h ha^{-1}). In the first hoeing treatment, when the weeds were small, the rolling harrow was used at a slow speed, consequently increasing its time (4.47 h ha^{-1}). This parameter, however, was lower than that recorded in the previous year for precision hoeing. This is probably because of the flaming treatment done in pre-emergence of the crop. The flaming treatment was performed at a

Table 5. Working time for physical weed control in the organic production system in the second year.

Working time	h ha^{-1}
Physical weed control	11
Sowing	4
Hand weeding	37
Total	52

Table 6. Characteristics and working time in the conventional production system in the second year.

Characteristics	
Transplanting time (h ha^{-1})	84
Spraying time (h ha^{-1})	6
Total (h ha^{-1})	90
Working productivity (ha ha^{-1})	0.16
Sprayed mixture (l ha^{-1})	1408

Table 7. Yield and weed biomass at harvest determined in 2006. In each column, means followed by the same letter are not significantly different at $P \leq 0.05$ (*t*-test).

Weed management system	Yield (Mg ha^{-1})	Weed dry biomass (g m^{-2})
Conventional system	36.9 ns	12.8 a
Organic system	33.4 ns	5.9 b

Table 8. Yield, weed biomass and canopy at harvest determined in 2007. In each column, means followed by the same letter are not significantly different at $P \leq 0.05$ (*t*-test).

Weed management system	Yield (Mg ha^{-1})	Weed dry biomass (g m^{-2})	Weed canopy (%)
Conventional system	30.6 ns	7.8 a	12.9 a
Organic system	30.8 ns	3.5 b	4.4 b

speed of 3.5 km h^{-1} (2.39 h ha^{-1}) and working pressure of 0.25 MPa with an LPG consumption of roughly 40 kg ha^{-1}. The working time of the last hoeing, carried out with the precision hoe with static tools, was also lower than that recorded in the previous year. Along with working time, fuel consumption was also reduced, in fact, fuel consumption was approximately half that of the first year. The trend in time reduction was also reflected in the time for hand weeding (37 h ha^{-1}); which was nearly seven times less than in the first year (Table 5).

In the conventional production system, the time for manual transplantation was nearly the same as in the previous year (Table 6), while the time for the herbicide application was slightly less (6.30 h ha^{-1}).

In the second year, the physical weed control strategy reduced labor input, especially hand weeding time (Table 5).

For the physical weed control system in the second year, the total working time was 52 h ha^{-1}, while it was 90 h ha^{-1} for the conventional farm.

Weed control and yield

In the first year experiment, physical weed control caused a progressive depletion of the seed bank in the first centimeters of soil layer. The weed flora was initially composed of *Picris echioides* L. (30% of relative density), *Veronica persica* Poiret (20%), *Rumex* spp. L. (20%) and winter annual and perennial grasses (17%). Weed density was 350 plants m^{-2} before using the stale-seedbed, 250 plants m^{-2} before the first hoeing, 100 plants m^{-2} before the second hoeing and 120 plants m^{-2} before the third hoeing pass. Weed control efficiency was 100% with the rolling harrow and over 90% with hoeing (taking into account in-row and inter-row space). Weed dry biomass registered prior to the second hand-weeding was triple compared to the first one (12 versus 4 g m^{-2}).

Weed density at the conventional farm before chemical treatment was approximately 150 plants m^{-2} with *Stellaria media* (L.) Vill. as the dominating species, 90% of density.

Weed dry biomass registered before the last crop leaf harvesting was 6 and 13 g m^{-2} for the organic and the conventional farm, respectively (Table 7). The most abundant species observed were *Rumex* spp. (13% of relative density), *P. echioides* (39%), *Conyza canadiensis* (L.) Cronq. (19%), *V. persica* (7%), *Anagallis arvensis* L. (6%), *Cerastium holosteoides* Fries. ampl. Hylander (6%) for the organic farm and only *S. media* (almost 100% of relative density) on the conventional farm.

There were no significant differences in total fresh yield between the two cropping systems, at the end of the first year of the experiment, concerning with total fresh yield (Table 7). However, yield in the conventional system was slightly higher compared with the organic one (on average, 37 versus 33 Mg ha^{-1}).

In the second year of this project, the weed density observed before the stale-seedbed preparations was approximately 400 plants m^{-2} in the organic cropping system. The weed flora density was mainly composed of *Solanum nigrum* L. (52% of relative density), *P. echioides* (22%), *C. canadiensis* (22%) and *Portulaca oleracea* L. (8%). However, the rolling harrow was 100% effective in controlling weeds prior to sowing. Furthermore, very few weeds re-grew after this treatment prior to crop emergence (about 10 plants m^{-2}). Pre-emergence flaming treatment was carried out to control the few weed species (for example *Cyperus* spp.) that were fairly developed (4–6 true leaves) to prevent their interference with crop emergence. Weed density was about 200 plants m^{-2} before the first hoeing intervention carried out with the rolling hoe. This treatment controlled approximately 90% of the weeds in the inter-row space and 30% of the weeds in the in-row space. Similar levels of weed control characterized the second

hoeing treatment, carried out by means of the precision hoe. Weed density before this intervention was approximately 100 plants m^{-2}. Moreover, one hand weeding intervention was carried out in order to reduce weed density in the intra-row space. Weed dry biomass was approximately 4 g m^{-2} and *Amaranthus retroflexus* and *Chenopodium album* were the most abundant and developed weeds.

In the conventional farm system, weed density before herbicide application was approximately 180 plants m^{-2}, and consisted almost exclusively of *S. media*.

Weed dry biomass and weed cover data collected before the last crop harvest showed significant differences between the two cropping systems. Organic plots were characterized by a significantly lower weed biomass (−50%) and weed canopy percentage (−65%) compared to the conventional ones (Table 8). The weed canopy assessments used the Braun–Blanquet ordinal scale and 16 different weed species were observed in the organic farm and only three in the conventional plots. This difference might be attributed to a weed selection action caused by the use of herbicides. However, a strictly selected weed flora could be very aggressive. In this case, the most widespread species was *S. media* for both cropping systems. Its canopy percentage value was approximately 87% for the conventional farm and 57% for the organic one. In addition, two other weed species reached relevant relative percentage values before the last harvest in the organic cropping system: *Conyza canadensis* and *C. album* (approximately 40% of relative density together).

The different results concerning weed flora composition should not be strictly related to the two cropping systems under comparison. Random factors and previous cultivation practices could also have made an important contribution. In fact, specialized 'flora' is a common feature of conventional farms, while organic systems are generally characterized by a more heterogeneous weed population.

Concerning the total crop fresh yield, there were also no significant differences in the second year. The observed value was approximately 31 Mg ha^{-1} for both the cropping systems and it was similar, even if slightly lower, compared with yields observed in 2006 (Table 8).

Conclusions

These experiments show that the use of physical weed control strategies can provide efficient weed control in leaf-beet produced under protected cultivation. In the first year of this project, the yield of the two cropping systems was very similar but the physical weed control strategy required much more labor than the conventional cropping system.

In the second year, the physical weed control strategy was improved and its labor requirements were reduced. Effectively, both cropping systems had similar yields with similar working times. In a global comparison of these two cropping systems, among the benefits of using physical weed control strategies is that a product of higher quality can be obtained along with a better price (on average in the two years, the prices on Central Italy market were 1.5 and 0.5 € kg^{-1} for organic and conventional leaf-beet, respectively).

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Evaluating marketing channel options for small-scale fruit and vegetable producers

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Abstract

An analytical framework and ranking system is developed to summarize the primary factors affecting marketing channel performance and to prioritize those channels with the greatest opportunity for success. An application of the model is conducted using case-study evidence from four small-scale diversified vegetable crop producers in Central New York. The relative costs and benefits of alternative wholesale and direct marketing channels are investigated, including how the factors of risk, owner and paid labor, profits, lifestyle preferences and sales volume interact to impact optimal market channel selection. Given the highly perishable nature of the crops grown, along with the risks and potential sales volume of particular channels, a combination of different marketing channels is needed to maximize overall firm performance.

Key words: local food, marketing, wholesale, direct, marketing channels, economic evaluation

Current food shopping trends indicate an increasing demand for local foods that is presenting new marketing opportunities for small-scale agricultural producers. Some indicators of this growing demand are reflected not only in the increased availability of local foods at traditional retail channels such as supermarkets or through wholesalers but also in the growth of direct marketing channels such as farmers' markets (FMs) and community supported agriculture (CSA) operations. US Department of Agriculture (USDA) estimates that the total US sales at FMs grew 13% from 2000 to 2005[1], and the number of FMs increased from 1775 in 1994 to nearly 4700 in 2008[2]. Likewise, the total number of CSAs in the US was only about 50 in 1990, but now that number exceeds 2200[3].

Wholesale channels typically have the ability to move large quantities of produce quickly and usually (but not always) at a lower price than through direct channels. Direct channels often feature higher prices, but require more customer interaction and time requirements of the producer. As such, producers are faced with the decision of whether to move larger volumes of produce through wholesalers at relatively lower prices or seek higher prices in direct markets and run the risk of lower volumes or unsold leftovers. Perhaps more important, given the nature of highly perishable crops, optimizing sales likely requires the flexibility of combining different channels capable of accepting alternative sizes and types of products, and/or absorbing potential unpredictable volumes.

While a great deal of research has investigated consumer responses and preferences for local foods, less attention has been focused on the producer side, particularly in identifying how producers identify their appropriate marketing strategies[4]. The existing literature has shown some potential for increases in farm returns through direct marketing; however, the evidence is mixed and depends on a host of spatial, market and demographic factors, as well as firm preferences that may not be financially based[5]. Common generalizations are problematic given that producers marketing through direct channels are a heterogeneous group with wide variation in farm characteristics, including farm size, employment status, labor resources and risk preferences.

Accordingly, the objective of this paper is to develop and illustrate an analytical framework and decision-making tool to improve decision-making acuity for small-scale diversified fruit and vegetable crop producers considering changes in their marketing strategies. Similar to Hardesty[6], the relative performance of wholesale and direct marketing channels is considered, including how the factors of owner and hired labor, prices and sales volume interact to impact profitability across channels, as well as the roles that risk preferences and lifestyle choices play when making farm marketing decisions. The decision-making tool is applied to data collected from four case-study farms in Central New York to highlight the relative costs and benefits of various marketing channels and illustrate the

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usefulness of the model in improving producer marketing decisions.

We continue now with a description of the conceptual model and its adaptation into a case-study framework. This is followed by a description of the data collected and alternative marketing channels utilized by the case-study farms. The channel assessment tool and its components are then described and applied to the set of case-study data collected. We close with a discussion of the empirical results, relevant conclusions and identification of areas for future research.

Methodology

Conceptually, economic theory tells us that to maximize net returns the producer should allocate output to each market channel such that marginal net returns are equal across channels. For example, consider the simple case of one crop with total farm output Q, and two marketing channels, direct (d) and wholesale (w). The producer's problem can be expressed as

$$\max_{Q_d Q_w} \mathrm{NR} = P_d Q_d + P_w Q_w - C_d(Q_d) - C_w(Q_w) - C(Q), \quad \text{subject to: } Q_d + Q_w = Q, \tag{1}$$

where NR is the total net returns, P_d and P_w are the expected output prices for the direct and wholesale channels, respectively, C_d and C_w are the respective marketing cost functions, and $C(Q)$ represents all other costs that do not vary across channels. Solving the first-order conditions for Equation 1 yields the familiar equi-marginal result:

$$\left(P_d - \frac{\partial C_d}{\partial Q_d}\right) = \left(P_w - \frac{\partial C_w}{\partial Q_w}\right), \tag{2}$$

where $(\partial C_d/\partial Q_d)$ and $(\partial C_w/\partial Q_w)$ are the marginal marketing costs for the direct and wholesale channels, respectively. Equation 2 highlights the importance of considering differences in both output prices and marketing costs when evaluating alternative channels. In addition, marginal marketing costs are likely to decrease as the total output allocated to a channel increases, reflecting economies of scale in marketing. As will be shown below, marketing costs can vary considerably across channels, so a producer's interest in getting higher retail prices in one channel may well be offset by higher marketing costs.

Small-scale producers oftentimes fail to account for their own or others' unpaid labor when making production and marketing decisions[7–9]. When these costs are not well understood or considered the result can be a marketing channel portfolio that does not accurately reflect the optimal decision for that producer. This practice is particularly problematic for small-scale fruit and vegetable producers because labor requirements and costs have the biggest impact on profitability when comparing different channels[6,10].

While the producer's problem posed above is straightforward, it is deficient for our analysis for two primary reasons. First, the model fails to account for the perishable nature of many of the crops marketed. The level of perishability will affect the length of the marketing windows for many of the crops and oftentimes necessitates the use of multiple channels to avoid losses due to spoilage. The second limitation of the model is that it fails to account for such factors as a producer's level of risk aversion, lifestyle preferences and other similar attributes. These types of factors are often a vital part of the decision for smaller producers who grow and market fresh vegetables[7,11,12].

A more complex model factoring in these limitations is beyond the scope of this study. In addition, cost and returns data collected for this study were limited to four case-study farms over a typical peak-season week. Further data would be necessary to accurately reflect timing effects throughout the season and to estimate the marketing cost functions. Furthermore, the problem could be more appropriately framed within a household production function and utility maximization framework that values and accounts for household labor decisions dedicated to production, marketing and leisure. To accommodate these issues, an alternative case-study approach is presented.

Case-Study Farm Data

Information on costs and returns were collected from four successful small-scale fruit and vegetable farms in Central New York. The farms were intentionally selected to illustrate a diverse array of marketing channels. Given the limited number of farms, we do not purport that the channel-specific data are necessarily representative of typical channel performance for the larger underlying population. However, the use of the data remains useful in highlighting the important inputs needed and outputs generated from the channel assessment tool.

Wholesale marketing channels are defined as those channels for which sales are to a buyer who is not the ultimate end user. Wholesale channels utilized by the case-study farms included selling to restaurants, grocery stores and distributors. Direct marketing channels are defined as those channels for which sales are made directly to the end user. Direct channels utilized on the case-study farms included CSA, farm stand (unstaffed), FM and u-pick (staffed) operations. A summary of the farms and the marketing channels utilized are shown in Table 1. All of the farms have been in operation for over 5 years, and have between 7.3 and 8.1 ha in diverse vegetable and small fruit production.

Labor data for specific marketing activities were collected from each farm, as well as distances traveled, employee labor rates and gross sales. Each item was categorized by marketing channel in order to assess the channel-specific costs and returns. To get a better sense of the farm production and marketing operations, multiple interviews were conducted with the farm owners and employees. In addition, a survey was conducted among 14 local diversified fruit and vegetable growers to gain a more

Table 1. Case-study farm comparison and marketing channels utilized.

Characteristics	Farm 1	Farm 2	Farm 3	Farm 4
Hectares in production	7.3	7.3	7.3	8.1
Number of crops grown				
Vegetables	18	13	19	8
Fruits	5	0	2	9
Total	23	13	21	17
Organic/conventional	Conventional	Organic	Organic	Conventional
Direct channels				
CSA[a]		X	X	
FM	X		X	X
Farm stand	X			
U-pick				X
Wholesale channels				
Restaurant		X	X	
Retail/grocery	X	X	X	X
Distributor		X	X	

[a] CSA, community supported agriculture.

complete understanding of farmers' perceptions regarding marketing channel risks.

Consistent with Hardesty[6] and in interviews with the farm operators, it was clear that, regardless of channel, the major marketing cost for each farm was labor. This is also consistent with Uva[10], who found that labor constraints were the main barrier to direct marketing by vegetable farms surveyed in New York. While each channel has additional costs, such as packaging materials and market fees, labor is by far the largest cost component.

During 1 week of the study (August 4–10, 2008), the owner(s) and employees of each farm were asked to keep daily activity logs to determine how labor was devoted to various marketing activities during a 'typical' peak-season week. Logs were completed by all farm staff, including owners, hired staff, unpaid family members and volunteers. The particular week was chosen through interviews with the farmers. August is the beginning of 'peak season' for many specialty crops and the August–October period represents the highest gross sales volumes and largest diversity of marketable crops for specialty crop growers in the area. In addition, the proportion of sales through each marketing channel was consistent with the previous year. Finally, each farmer was interviewed at the conclusion of the week to learn if there had been any unusual incidences that might skew the data, such as key employee absences, severe weather affecting either activity on the farm or at a market, unusually high or low sales, or crop failures.

Only labor activities from harvest to market were tracked. Production activities are expected to be the same across channels and were excluded. In interviews, farmers stated that their production activities (i.e., planting, cultivating, fertilizing, irrigating, weeding, etc.) did not vary for a crop based on its marketing channel destination. In fact, most crops were grown with more than one market destination in mind, but all were treated the same until the point of harvest. Harvest activities are included in marketing labor because it was determined through these same interviews that harvest activities vary depending on the marketing channel (e.g., bunching and tying beets in the field for wholesalers versus harvesting loose for a FM).

The average hourly rate paid to hired staff was US$8.46 (median = US$8.25) and ranged from US$6.50 to US$13.89 across all farm employees. To assign a labor value for unpaid volunteer, family member and owners' time, a conservative hourly rate of US$8.50 was used.

For purposes here, profitability is defined as gross sales minus marketing labor and travel costs. Wholesale prices received by farmers are prices for goods delivered by the farm. For the CSA marketing channel, farms are paid at the beginning of the growing season in exchange for a weekly share of produce, which made the week's gross sales value difficult to assess. As such, we relied on values assigned by the farmer for produce marketed through CSAs, which were the same or similar to the farms' wholesale prices received.

It should be noted that the sales and cost values for the u-pick channel represent data from just one farm since only one of the four farms offered u-pick. Similarly, the farm stand channel is represented by only one farm, and operates unstaffed with an honor system for payment. Given the small sample size of farms ($N = 4$) and even smaller number of farms participating in each of the channels outlined here, it is important to re-emphasize that the empirical results are not assumed to be representative of each channel's performance, but are used to facilitate the discussion and usefulness of the firm decision-making tool developed.

Marketing Channel Activities

Small farm marketing can generally be divided into four activities: harvest, process and pack, travel and delivery, and sales time. Given that two of the four farms utilized all three wholesale channels with similar product

requirements, it was difficult to separate the harvest and processing activities for these channels. Accordingly we combine all three wholesale channels into one composite channel.

Harvest

Harvesting is the process of gathering saleable produce from the fields and, for a diverse group of fruits and vegetables, can be a very time intensive activity. In particular, for small-scale farms hand-harvesting tends to be conducted on all or nearly all of the crops harvested. The amount of labor devoted to harvest varies depending on the marketing channel but, in general, is higher for the wholesale channels. Wholesale markets typically require products of a consistent size and quality and packing to standardized case weights. Additional labor is also required to sort and bunch crops for wholesalers as they are harvested in the field.

Processing and packing

Process and pack activities include: culling, grading, sorting, washing, bagging, packaging, and packing orders and boxes. Processing produce, like harvesting, varies depending on the marketing channel. Produce destined for wholesale buyers requires a higher degree of washing, culling, grading and packaging than does the same produce destined for direct sales. In particular, wholesale customers demand produce of consistent size, while farmers report that direct marketing customers are satisfied with irregularly shaped and sized produce.

Travel and delivery

Transport time includes travel to and from FMs, satellite farm stands, and deliveries to restaurants, grocery stores and distributors. Also included is time spent loading and unloading produce. Grocery stores, restaurants and most distributors require delivery. While many CSAs have a member pick-up day at their farm, customers are sometimes offered additional locations, or delivery is available for an extra fee.

Sales

Sales time includes 'face time' with customers, time spent invoicing, making sales calls, creating daily harvest sheets or price lists, and doing other administrative tasks. Direct sales channels generally require a higher level of customer service and a positive, friendly attitude; however, they can also provide producers with valuable customer feedback on buying preferences and price sensitivity. Some farmers enjoy interacting with consumers and consider selling in the direct channels a rewarding community event and an opportunity to build their farm's brand. While some view customer interaction as a bonus, not everyone is skilled at interfacing with customers in this way.

Marketing Channel Results

Data collected from the farms were used to analyze each channel's performance with regard to sales volume, profit, labor requirements and risk preferences. All metrics are then integrated together to consider the aggregate performance across a suite of channels utilized.

Sales volume

The volume that can be sold through a given channel has a large impact on profitability. The more perishable the crop, the more important it is to have a channel that can absorb the volume harvested as quickly as possible. Optimizing sales of perishable crops requires the flexibility of combining different channels capable of absorbing unpredictable volumes. The general trade-off between relatively high- and low-volume marketing channels is price. However, despite lower prices, high-volume channels offer the benefit of increased efficiency in the harvest and production process.

The total volumes sold by the case-study farms during the studied week illustrate the relative volume capacity of each marketing channel. The average volumes sold for each channel were derived from the group's total gross sales for the week and normalized relative to the FM sales volume average. For this group of farms, wholesale channels were able to sell roughly 3.4 times as much (in value) as FMs even though they offered the lowest price (Table 2, column 2).

CSA, the next highest volume, offered the same or slightly higher prices than wholesale outlets. Given an adequate number of shares sold up front, CSAs can consume large volumes. In addition, it is always possible to give members more in their share if a particular crop is plentiful, but this does not translate into more income, just less wasted produce. U-pick, the third highest volume marketing channel, also offers a relatively low price compared with other direct marketing channels.

Profits

While sales volumes are important, returns relative to costs are also important for long-run firm viability. From our case-study farms, we compute the average profit percentages by market channel, calculated as net returns relative to gross sales (i.e., gross sales less marketing labor and mileage costs, then divided by gross sales). The results are shown in Table 2 (column 4).

In this case, the CSA channel was shown to have the highest profitability percentage, followed closely by the unstaffed farm stand. As expected, per dollar of gross sales, the profitability of the wholesale channel was the lowest. This highlights the trade-off in volume versus unit profits, but both should be considered in making marketing channel choices.

Table 2. Market channel evaluation and ranking (four case-study farms).

Market channel	Sales volume[a]		Average profit[b]		Labor required[c]		Risk[d]	Final scores[e]	
	Volume index	Scaled rank	Profit (%)	Scaled rank	Labour index	Scaled rank	Scaled rank	Un-weighted	Factor-weighted
CSA	1.7	3.8	87	1.0	1.0	1.0	1.0	1.7	2.1
Farm stand (unstaffed)	1.3	4.5	82	1.7	1.5	1.8	3.0	2.8	3.0
Wholesale	3.4	1.0	58	5.0	1.9	2.5	5.0	3.4	2.8
U-pick w/farm stand (staffed)	1.5	4.2	62	4.4	3.4	5.0	2.0	3.9	4.2
FM	1.0	5.0	67	3.8	3.0	4.3	4.0	4.3	4.4
Factor weights[f]	0.40		0.25		0.25		0.10		

[a] Normalized volume index scores based on computed dollar volume sales. The scaled rankings range from 1 to 5 (the number of channels evaluated), where 1 is the 'best' and 5 is the 'worst'. The scaling considers how far apart the factor scores results are from each other.
[b] Average profit percentages per dollar of gross sales are calculated as 100*[(sales − (labor + mileage)/sales].
[c] Normalized labor index scores based on computed labor hours per sales dollar.
[d] Risk ranking based on farmer survey overall rankings.
[e] Final scores represent average scaled rankings across factors, either un-weighted or factor-weighted. The lowest score represents the highest performing channel. Channels scoring low and near to each other indicate preferred multiple-channel options.
[f] The factor weights used here are for illustrative purposes only, where sales volume is the most important factor (0.40), risk is the least important factor (0.10), and labor requirements and per unit profits are somewhere in between (0.25). Individual factor weights should be from 0 to 1, and the sum over all weights must equal 1.

Risks preferences

In addition to the normal production risks of weather and pests, each marketing channel offers a set of risks to the producer. Marketing risk comes in many forms, including market demand for a crop, price, competitors, failure to offer a diverse selection and low volume sales. Additional risks include the possibility of low customer turnout resulting in unsold product.

In a survey conducted with the case-study farms, as well as additional Central New York vegetable farms, farmers were asked what they felt were the primary risks associated with each channel. When asked open-ended questions about risks, respondents did not adhere to the strict meaning of risk, but also listed drawbacks and challenges. In any event, the responses were categorized into seven basic challenges: low volume sales, high labor and marketing costs, the ability to provide product of consistent quantity and quality, buyer failure to fulfill commitments, competition, unpredictable customer turnout, and low prices and profits. Table 3 illustrates the frequency that each challenge was mentioned.

The results show that fear of low sales volume was an issue with the restaurant channel and most often for FM (Table 3). As an example, interviewed farmers indicated that approximately 20% of produce harvested and brought to a FM goes unsold. Low prices are a risk created by competition from other farms, other channels, or result from a market flooded with a certain item.

Farmers revealed their fear of commitments with wholesale buyers when they identified the risks of buyer-back-out and crop failure (Table 3). While crop failure is a concern for all channels, the case-study farmers clarified that they are more stressed over crop failure with wholesale channels due to the commitments they have with buyers. Farmers were also concerned about wholesale customers backing out of orders if their needs change suddenly, if they refuse produce due to poor quality, or if they turn to another supplier.

The two main reasons given for avoiding a particular marketing channel amongst the case-study farms were life-style preferences and stress aversion. Wholesale channels tended to create stress because they required higher levels of product preparation, product specifications and volume commitments. Distributors were also perceived to be very demanding, where producers must accept dictated prices, deadlines and delivery logistics. Alternatively, direct marketing channels were perceived as relatively low stress. This was particularly mentioned with the CSA channel that may have lower expectations in terms of processing and packaging.

Each of the direct marketing channels, except for the CSA, aroused concerns over customer turn out (Table 3). Factors such as weather, location, competing events and the availability of parking were all mentioned as risks when direct marketing. Low customer turn out implies the possibility of increased wasted produce due to non-sales. However, the case-study farms indicated that having a marketing strategy that combines wholesale and direct channels minimizes wasted product.

The most frequently cited concern regarding all marketing channels was high labor and marketing costs (Table 3). Of the direct channels, high marketing costs were most frequently mentioned for FMs that tend to be labor

Table 3. Number of risks and challenges associated with marketing channels, survey of 14 Central New York vegetable producers.

Risk or challenge	CSA	U-pick	Farm stand	FM	Restaurant	Distributor	Grocery
	Number of producers selecting						
Low sales volume, unsold produce	1			3	1		
High labor and other marketing costs			3	7	2	5	2
Ability to provide consistent quality and quantity	2	1		2	2	1	2
Market competition				1			1
Unpredictable customer turnout		2	2	2			
Low prices and profits						4	1
Buyer back out, failure to fulfill commitments					1	1	1
Other	1	1	1			1	1

Table 4. Summary of marketing channel associated costs.[a]

Item	FM	CSA	U-pick	Farm-stand	Wholesale: R/G/D
Reusable plastic crates	R	X	O	R	R
Single-use cardboard produce boxes	O	O	O	O	X
Twist ties, packaging, containers and bags	X	O	NA	R	X
Customer shopping bags	X	O	X	X	NA
Farm sign(s)	X	X	X	X	NA
Building/tent, tables and chairs	X	X	X	X	X
Cash register, scale and calculator	X	NA	X	X	NA
Pricing signs	X	NA	X	X	NA
Market fees	X	NA	NA	NA	NA
Brochures and flyers	O	R	R	O	O
Advertising	NA	R	R	O	NA
Transportation and delivery	X	NA	NA	NA	X
Washing/sorting equipment	O	O	NA	O	R

[a] X = necessary, R = recommended, O = optional, NA = not applicable, R/G/D = restaurant, grocery store or distributor.

intensive and carry additional marketing costs, such as market fees, advertising and travel. The wholesale channel cited as having the highest marketing costs was the distributor. Respondents mentioned a high level of labor needed to solve the 'logistical headaches' of delivery, the high level of quality control work and the added 'time and energy for good service' when selling wholesale.

Labor requirements

While surveyed farmers perceived that wholesale channels were generally more labor intensive than direct channels, data from the case-study farms demonstrate that in wholesale, the return in gross sales for each hour worked is about the average of all channels evaluated. This is shown in Table 2 (column 6), where the hours of marketing labor per sales dollar are normalized on the CSA channel.

The FM and u-pick (staffed) channels required higher than average levels of labor to achieve the same level of sales. FM, farm stand and u-pick channels generally require a high degree of customer interaction and are channels that reward a tidy appearance and welcoming display. Of course, farm stands and u-pick sales can be conducted using honor system payment, but some minimal level of customer interaction is inevitable. CSAs require relatively little customer interaction except during weekly pick up times, but they may have newsletters or email updates for their members.

Wholesale customers require less interaction, except when discussing orders or making deliveries. Also, once a relationship is established with a wholesale buyer, sales calls take less time. Wholesale accounts allow more anonymity; however, promotion in the form of cases of free sample product is common.

Other channel-specific costs

While some operational costs are common among all marketing channels (utilities, equipment, insurance, licenses and certifications, vehicles, buildings, etc.), each channel has additional costs and requirements that are specific to that channel. A list of associated costs by marketing channel is summarized in Table 4. It is important to consider these associated costs when determining marketing channel choices; however, due to the potential for large variations in the scale of sales through each channel, the

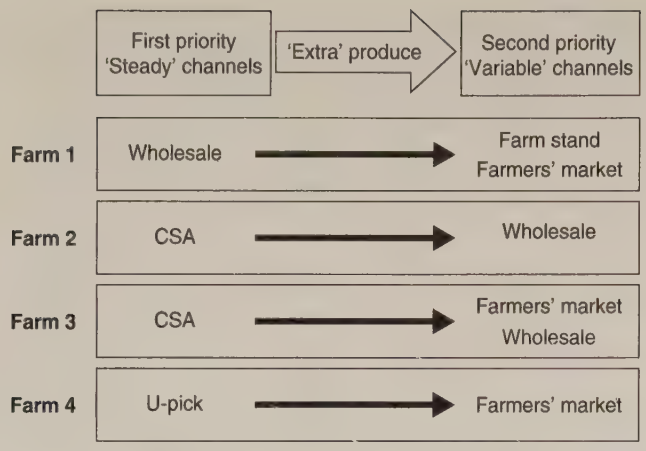

Figure 1. Marketing channel combinations used by case-study farms.

operator's chosen level of marketing management, and staffing, it is not useful to compare the channels in regard to these costs here. For more information on these costs see LeRoux[13].

Assessing a Marketing Channel Strategy

As discussed above, choosing the appropriate marketing mix includes consideration of many factors, including sales volume, profit, risk, lifestyle preferences, labor requirements and channel-specific costs. The weights (or importance) assigned to each of these factors is unique to the individual or firm. Additionally, the nature of highly perishable crops, along with the risks and potential sales volumes of particular channels, requires combining different channels to maximize firm performance.

Multiple channel strategies were utilized by all of the case-study farms. Figure 1 illustrates the different marketing channel strategies used by the farms that allowed them to diversify the sources of their income, as well as optimizing sales of unpredictable levels of harvest. Each farm has a 'steady' marketing channel with a relatively consistent demand, and represents the farm's first priority for the weekly harvest. Once that channel is satisfied, the farm's other channels can be supplied with additional harvest. Case studies in California similarly found that direct marketing, when used along with wholesale, can increase producers' overall profitability[6].

Channel ranking

To overcome the difficulty of comparing channels, a ranking system was developed to summarize four major factors influencing the performance of a channel (i.e., labor requirements, sales volume, profit percentage and risk preferences). Table 2 shows each channel's factor scores along with their relative rankings for this set of case-study farms. While the results reflect the combined information from all four farms, the tool is developed such that individual farm data are entered and evaluated across the specific channels utilized.

Each set of factor scores across channels is ranked from one (i.e., the highest rated channel for that factor) to five (i.e., the lowest rated channel for that factor) and scaled to reflect the relative distance between factor scores. The ranking of channel riskiness comes from the results of the 14-farm survey (Table 2, column 8). The scaled factor rankings for each channel are averaged in Table 2 to determine the final channel scores, either un-weighted (column 9) or factor-weighted (column 10). The use of factor weights allows individuals to give greater weight to those factors that may be more important to them than others. The lowest overall score is defined as the top performing channel; however, channels scoring low and close to each other provide some indication of preferred multi-channel strategies.

For our general case (assuming equal factor weights), the top performing channel across these four farms was the CSA, including top rankings for profit percentage, risk and marketing labor requirements. While individual farm results are likely to vary, the results are consistent with similar studies conducted in Wisconsin and California[6,11]. Wholesale channels ranked in the middle, primarily due to differences in labor requirements across the direct channel options.

The FM had the lowest overall ranking for this set of farms, although not the least profitable, suffering from a combination of higher labor demands and low sales volumes. Farmers participating in the case study ranged from $21.05 to $30.74 gross sales per hour of marketing labor when selling at FMs. While total hours of labor for FMs represented 30–37% of participating farms' labor during the case-study week, the channel only produced 28–30% of the same farms sales that week. That said, the FM can still be a useful resource for small-scale farmers, particularly new farmers, in terms of enhancing farm exposure and advertising for other channels utilized (e.g., wholesaling with chefs and other buyers). In fact, while the FM channel was ranked as one of the more risky channels, the producer survey revealed that producers enjoyed the experience and connection to their consumers and, thus, continued to participate.

Changes in channel rankings are evident when we assume differing weights across factors. In the example presented, more weight is placed on sales volume and less on perceived risks. In this case, the wholesale channel improves its ranking relative to the equal weight scenario, more readily suggesting a strategy that incorporates both CSA and wholesale channels.

Conclusions

Conducting accurate assessments of marketing channel choices by small-scale farmers requires increased attention toward proper record-keeping to properly account for sales, labor requirements and other associated costs. In addition,

failure to account for owner/family unpaid labor contributions can result in channel selections that reduce overall firm performance. In fact, the 'hidden operator labor costs' can go a long way in explaining farmer misconceptions regarding the profitability of various channels.

A marketing channel assessment tool was developed and applied to a set of four small-scale fruit and vegetable farmers in Central New York. For this set of farms, it was revealed that the CSA was the top performing channel, based on ranked factors of volume, unit profits, labor requirements and risk preferences. However, given the perishability of many of the crops marketed and potentially unpredictable harvest volumes, optimizing sales requires the flexibility of combining different channels. For our group of case-study farms, augmenting the direct channel CSA with wholesale outlets was preferred.

The relative performance of marketing channels may be different for other firms based on their specific farm marketing activities and market areas operated in. Combined with careful data collection of channel-specific marketing labor activities and sales, the channel assessment tool aids in informed decision-making for producers wishing to change their marketing mix, increase profitability or decrease the amount of labor involved in their current marketing activities.

While the approach offered here presents a useful method for evaluating market channel choices, the analysis would benefit from increased data collection from a larger variety of fruit and vegetable producers, differentiated by firm size, location and channels utilized. Such additional information will allow for refinement of market factors most important in optimal channel decisions, provide additional information on a larger set of wholesale and direct marketing channels, and facilitate the development of channel-specific, representative benchmark estimates. Paying careful attention to these issues is a top priority for our continuing research.

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Determining marketing costs and returns in alternative marketing channels

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Abstract

Direct marketing is a popular marketing practice among smaller producers in the United States. We conducted detailed case studies of three organic farming operations of different sizes and compared their marketing costs and profitability in alternative marketing channels. We classified marketing-related activities into three categories: packing and storage, transportation, and selling and administration. By measuring the costs for labor, purchased goods and services, and capital assets associated with these marketing activities, we determined that there are significant variations in marketing costs across marketing channels. For each of our three case-study farms, marketing costs per dollar of revenue were lowest in the wholesale channel and highest in the farmers' market channel. Significant labor costs for the selling activity and transportation expenses offset the higher prices and minimal packaging costs associated with farmers' markets. Profitability can also be significantly affected by marketing factors, such as packing and grading standards, and product that is used for sampling and consumer premiums. Our research demonstrates that the higher prices that producers earn from direct marketing rather than wholesaling are not pure profit; the price premiums are compensation for the costs they incur when direct marketing their produce. Direct marketing channels, such as farmers' markets and Community Supported Agriculture (CSAs), can enable smaller farmers to build financially viable operations, by gaining access to markets, growing their farming operations and reducing their marketing risk. However, to achieve this success, farmers must manage their marketing costs as well as their production costs.

Key words: farmers' markets, Community Supported Agriculture, financial management, small farms

Introduction

Direct agricultural marketing in the United States, particularly farmers' markets, has emerged as an alternative to the highly industrialized and consolidated grower–processor–retailer food marketing system. Nationally, the resurgence of direct marketing is linked to the passage of the Farmer-to-Consumer Direct Marketing Act of 1976; subsequently, numerous states enacted regulations to support direct agricultural marketing programs. Thirty-three years later, there are more than 4685 farmers' markets operating across the nation[1]. Other forms of direct marketing—including Community Supported Agriculture (CSA) programs, roadside stands, 'pick-your-own' operations and sales through the Internet or mail order—have also grown in popularity. Between 2002 and 2007, farmers' revenues from direct marketing rose by 49%, from $812 million to $1.211 billion[2].

Numerous programs supporting sustainable agriculture and/or small farms, such as USDA-AMS, National Sustainable Agriculture Information Service (ATTRA) and various university small farm programs advocate the use of direct marketing. These organizations advise smaller producers that direct marketing can enable them to market volumes that might otherwise be too small for conventional marketing outlets and to earn higher profits by bypassing food system intermediaries and capturing a greater share of the consumer dollar.

However, there is a dearth of information available regarding the costs producers incur when they engage in direct marketing and the profitability of direct marketing. While producers can charge higher prices when marketing direct to consumers, they could also have higher marketing costs than when selling wholesale. Recent articles in the popular press indicate that some producers are reconsidering their participation in farmers' markets. Several high profile producers of the well-known Ferry Plaza Farmers' market in San Francisco opted to quit or reduce their participation in the market, stating that it was no longer profitable and/or that it was too time-consuming[3]. The

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executive director of a large Southern California farmers' market association commented that farmers spend an inordinate amount of their time away from their farms to travel to and sell at farmers' markets[4]. These concerns are similar to those expressed by Thilmany and Watson[5], who concluded that while farmers' markets are expected to grow in popularity, producers' need to balance their marketing activities with the requirements of their production efforts made it difficult for some markets to attract producers.

Thus, the objective of our study was to compare the relative marketing costs and profitability of different types of direct marketing programs relative to the conventional produce wholesale market channel. After a brief review of the literature regarding direct marketing, we describe how we measured the marketing costs producers incur when they engage in direct marketing and present the findings for our three case studies. We then examine the impact of the marketing costs on profitability in different marketing channels. We conclude with an assessment of the cross-channel synergies and prospects for such alternative systems.

Background

Although there are numerous guidebooks concerning starting and operating direct marketing programs and articles regarding consumer interest in farmers' markets and other forms of direct marketing, research regarding the costs and profitability of direct marketing is very limited. Research by Stephenson and Lev[6] supports the use of direct marketing to earn higher prices; they determined that development of more localized food systems utilizing direct marketing in two contrasting Oregon communities could enhance the viability of small farmers.

Brown et al.[7] determined that farmers' markets provide an essential market outlet for many small farms in West Virginia. Park and Lohr[8] used data from the 2001 nationwide Organic Farm Research Foundation's survey to analyze the effect of diversity in marketing outlets by organic producers on gross organic farm incomes, rather than profitability. They concluded that producers who sell through all three channels (direct to consumers, direct to retailers and/or restaurants and wholesale) or a single channel (any single channel—not necessarily just direct to consumers) tend to have higher gross organic farm income than those who sell through two channels. In their data set, 36.3% sold through two channels and 15.5% of the producers sold through all three channels.

Kambara and Shelley[9] addressed the extent to which direct marketing improves the viability of existing operations in California. Twenty-eight percent of the producers they surveyed indicated that they started direct marketing in order to capture higher profit margins, and 63% identified direct marketing as the more profitable channel. Researchers at Rutgers University assessed growers' satisfaction with their returns at farmers' markets; they concluded that the prospects for direct marketing will depend on farmers' ability to sell sufficient volumes at favorable prices. Additionally, they noted that although the majority of the farmers participating at farmers' markets were satisfied with their profit margins, '. . .Harvesting, packing, loading, and transporting the products to farmers' market locations are all labor-intensive activities and require a reliable labor supply.' (Govindasamy et al.[10], p. 85).

Direct marketing also requires producers to be more involved in the promotion of their products; for example, most CSA programs included a newsletter with each delivery, and most farmers invest in signage and other display materials when they sell at farmers' markets. Producers need to account for the effort and expense involved with such activities when they shift from the conventional wholesale market to direct marketing. Our methodology for measuring marketing costs is described below.

Measuring Marketing Costs

To compare the marketing costs and profitability of different marketing channels, we began by identifying the relevant marketing activities and measuring the costs associated with these activities. First, we compiled a detailed list of post-harvest activities involved in getting product from the field to consumers by reviewing direct marketing handbooks and using our personal experiences. We subsequently grouped these activities into three categories—packing and storage, transportation, and selling and administration (see Table 1); these activities are described in the next section when we compare the extent of the activities between marketing channels. We included the full amount of uncollectible accounts under administration. The marketing activities utilized labor, capital assets, and purchased goods and services. We noted that an individual activity could serve more than one marketing channel simultaneously. We chose to ignore all costs involved in crop production by assuming that these costs were independent of the choice of marketing channel.

We selected a case-study approach because of the level of detail and effort that would be required to obtain the data for our analysis. Our case studies included three established producers in Northern California who have been actively marketing their produce through all three channels; we classified these operations as small-, medium- and large-sized farms. These operations are similar in the following ways:

- all are certified organic by California Certified Organic Farmers (CCOF);
- all are owned and operated by farmers who have been farming organically in Northern California for at least 12 years;
- they are located within a 50 mile driving distance from each other;
- all have highly diversified cropping patterns, growing a wide variety of vegetables year-round, as well as some fruits;

Table 1. Marketing-related activities and costs.

Activity and/or cost	Description
	Sorting and packing
Sort and pack product—facilities and equipment	Depreciation, utilities, maintenance and other operating costs for facilities used exclusively for each channel's activities, and/or costs of shared facilities. Costs of shared usage are allocated proportionate to sorting/packing labor hours for each channel
Sort and pack product—labor and materials	Labor costs include time for all operations after product is brought in from field, including washing, sorting, bagging, bunching, boxing, labeling and storing. Materials costs include boxes, labels, ice, ties, etc.
Load, unload truck—labor	Includes only time to load truck at farm for delivery route or farmers' market, and time to unload truck upon return
Maintain market supplies and equipment—labor	Labor to clean and maintain sales equipment, including reusable bins, signs, scales, tables, tents, restock selling supplies (plastic bags, etc.)
Training and supervision—labor	Labor for training and supervision of packing/sorting labor
	Transportation
Delivery vehicle—capital and operating costs	Costs to own, maintain and operate delivery vehicles, including fuel, insurance, maintenance and parts, registration and depreciation. Mixed load costs allocated proportionate to product value for each channel in the load
Delivery—labor	Labor to drive to and from each channel's sales or delivery sites. For farmers' markets, delivery labor includes driver's time for entire farmers' market set-up, sales and reloading time, as well as driving time For mixed loads, actual driving time only is allocated to each channel proportionate to product value for each channel in the load
Contracted trucking	Transportation charges for contracted trucking
Tolls	Tolls, allocated proportionate to product value for each channel in the load
Driver training and delivery management—labor	Hiring, training, supervision of driver, dealing with delivery problems, arranging routes and loads, negotiating repairs and rentals if needed, etc. Allocated proportionately to delivery labor hours used by each channel
	Selling and administration
Market communications—labor	Labor to attend conferences, network, communicate with marketing partners—site hosts, market managers, brokers, distributors, other farmers, advocates and associations
Wholesale sales—labor	Labor to discuss orders by phone, negotiate prices and quantities available, create invoices, schedule deliveries, communicate with picking and packing staff about availability and special orders, create pick list, update and change invoices. Compile availability list and distribute as needed to buyers
Retail sales—labor	Labor to sell to individual customers, including restaurants picking up pre-orders. Tasks include set up and take down stall, restock product, keep stall clean, offer product samples, etc., donate unsellable product and clean up
Marketing materials costs—labor and materials	Labor and materials used to create, maintain and update web site, ads, brochures, signage, newsletters, display materials, etc. Include fees for consultants
Sales staff administration—labor	Administration, training and supervision of sales staff
Office facilities, equipment, supplies, services use	Cost of office space, equipment, supplies, postage, used exclusively and/or shared. Includes rent or depreciation of office space and equipment, plus utilities, phones, internet, office supplies and services, etc. allocated proportionately to office labor hours used by each channel
Recordkeeping systems	Recordkeeping software development or purchase costs
Account maintenance, banking, bookkeeping—labor	Labor for on-going maintenance of accounts: receive and process payments, issue invoices, update contact info, etc. Prepare receipts for deposit. Prepare start-up bank for next sales day. Respond to customer inquiries/complaints. Maintain, update record keeping system. Pay bills
Other office staff—labor	Labor for personnel administration, payroll, general office maintenance, general communications and updating of certifications
Business planning—labor	Determine marketing strategies, prices, policies, equipment needs and sales goals

- all market their products through at least the three marketing channels analyzed in this study:
  - regular, year-round farmers' market sales,
  - Community Supported Agriculture type subscription delivery programs (all have year-round weekly deliveries of boxes of seasonal vegetables and fruits to retail subscribers who pick up the boxes at drop sites in their neighborhoods), and
  - wholesale sales to produce resellers, including direct delivery to distributors, stores and restaurants.

Table 2. Characteristics of participating farms.

Variable	Small farm	Medium farm	Large farm
Acres	20	70	240
Full-time employees (year-round-excluding operators)	2	7	30
Total revenues	$229,013	$627,046	$2,276,818
Wholesale revenues	$45,086	$131,611	$1,607,769
Farmers' market revenues	$50,363	$196,960	$435,126
CSA revenues	$133,564	$298,475	$233,923
Wholesale—% of total revenues	19.7%	21.0%	70.6%
Farmers' market—% of total revenues	22.0%	31.4%	19.1%
CSA—% of total revenues	58.3%	47.6%	10.3%

These operations vary significantly in size, as measured by both acreage and sales revenues (Table 2). They have the same relative rankings for all of the parameters in Table 2, except for CSA revenues; the medium farm has the highest CSA revenues, which comprise almost half (47.6%) of its total sales. CSA revenues represent 58.3% of the small farm's total revenues, but only 10.3% of the large farm's revenues. Direct marketing was a significant revenue source for both the small and medium farm, generating four-fifths of their total revenues.

The large farm's predominant marketing channel is the traditional wholesale market (70.6% of its total revenues), which has been its primary growth channel during the past 5 years. Unlike the small and medium farms, the large farm markets year-round in the wholesale market. While all three farms utilize seasonal workers to help in planting and harvest activities, they also rely heavily on the continuity provided by their full-time year-round employees. Only the large size farm provides full health insurance coverage for its year-round employees.

We conducted a series of interviews with the producers and their key employees to obtain background information about their operations, reviewed their financial statements and collected additional information about their marketing practices. We asked the producers to trace the flow of product after harvest to each type of market. Next, we asked each producer to describe the chronological sequence of events involved after they harvested their crops until the produce was sold. Since the case-study operations market year-round, the sequence was examined separately for each day of the week for the seasons (winter and summer) and for each marketing channel. We elicited estimates of the staffing and hours of labor involved for each marketing activity in each marketing channel type. For each activity, we determined what purchased goods and services (such as gas, packaging materials and utilities) and capital assets were utilized. The capital assets included a diverse collection of buildings and equipment, such as packing sheds, office buildings, coolers, ice makers, produce washers, packing lines, forklifts, holding bins, labeling machinery, scales, delivery trucks, software and office equipment.

Each producer also provided a detailed set of their financial records for 2005. We obtained the following information for the capital assets: original cost, year put into service and total years of expected use. Using these values and the straight-line method, we calculated depreciation expenses for each asset during 2005, rather than using depreciation expenses reported in tax returns. Our approach is consistent with the cost of production methodology utilized in the University of California Cooperative Extension's Cost and Returns Studies (for example, see Fake et al.[11]). We also followed the university's practice of including the opportunity costs of capital (using short-term rate of 7.50% for operating capital and long-term rate of 6.01% for capital costs, including depreciation, for 2005). Consistent with the university's cost study methodology, we valued operator labor at the same rates paid to hired labor for the same activity, rather than applying a higher rate that would reflect the opportunity cost of their managerial effort.

LeRoux et al.[12] also utilized a case-study approach in their analysis of marketing channel options for small farms in Central New York; however, they limited their measurement of marketing expenses to labor and mileage. Their four case-study farms were all small scale; two of the four were organic producers. They supplemented the case studies by surveying 14 growers regarding their perceptions of marketing channel risks.

Costs of Marketing Activities

There is significant pre-harvest selling activity in both the wholesale and CSA markets. Sorting, packing and storage activities vary across marketing channels. Product sold through the wholesale channel using distributors has to meet specific pack and grade standards; also, this channel requires less ripe fruit since it will be subject to additional handling and time delays. There are no packing standards for produce sold in farmers' markets or to CSAs.

Transportation requirements vary; sometimes, wholesale and/or CSA market deliveries are combined with trips to farmers' markets and CSA deliveries are combined on a regular delivery route. Farmers' markets involve significant sales effort, since direct contact is involved with individual customers. Administrative activities are similar across the channels, although a higher share of administrative time is needed to maintain the numerous individual CSA accounts than the fewer, but larger, wholesale accounts.

The data presented in this section are not meant to be representative of the marketing costs of typical diversified fruit and vegetable farms of specific sales size categories in Northern California. Rather, these data are used to explain the potential for differences and similarities in marketing costs across marketing channels and operations of different sizes.

Depreciation expenses related to marketing activities were low; they ranged from 1.9% of total marketing

Table 3. Marketing-related labor expenses by farm and marketing channel.

Farm and expenses	Marketing channel			
	All channels	Wholesale	Farmers' market	CSA
Small farm				
Cash labor expenses	$37,677	$6623	$17,175	$13,878
Imputed (operator) labor expenses	$51,240	$4001	$16,368	$30,872
Total labor expenses	$88,917	$10,624	$33,543	$44,750
% of total channel expenses	78.6%	67.1%	83.6%	78.3%
% of total channel revenues	38.8%	23.6%	66.6%	33.5%
Owner labor share of total labor	57.6%			
Owner labor share of total expenses	44.2%			
Medium farm				
Cash labor expenses	$107,552	$12,127	$39,255	$56,170
Imputed (operator) labor expenses	$21,714	$2459	$14,825	$4430
Total labor expenses	$129,266	$14,586	$54,080	$60,600
% of total channel expenses	58.6%	53.9%	62.7%	56.4%
% of total channel revenues	20.6%	11.1%	27.5%	20.3%
Owner labor share of total labor	16.8%			
Owner labor share of total expenses	8.5%			
Large farm				
Cash labor expenses	$304,305	$166,974	$95,020	$42,311
Imputed (operator) labor expenses	$45,759	$19,411	$17,262	$9086
Total labor expenses	$350,063	$186,385	$112,282	$51,397
% of total channel expenses	51.4%	41.6%	74.6%	63.0%
% of total channel revenues	15.4%	11.6%	25.8%	22.0%
Owner labor share of total labor	13.1%			
Owner labor share of total expenses	6.1%			

expenses for the small farm to 5.4% for the large farm. Most of the depreciation related to equipment, rather than buildings. Thus, there was limited substitution of capital for labor for marketing activities as farm size increases.

Not surprisingly, labor was the highest marketing expense item for all three farms (Table 3). Although labor expenses as a proportion of total expenses decreased with farm size, they nevertheless represented slightly over half (51.4%) of the large farm's total marketing expenses. The small farm had the largest share of labor provided by the owner; this was expected since the number of employees increased with farm size.

For all three farms, the proportion of labor expenses to total marketing expenses was highest for farmers' markets and lowest for the wholesale market. Most labor expenses for marketing at farmers' markets are incurred before selling begins at the market; thus, adverse weather conditions or a competing event can be very costly for farmers' market producers. The medium farm's labor expense ratios did not vary as widely as they did for the other two farms.

The labor/revenue ratio is a significant indicator of the returns in each marketing channel. It was the highest in the farmers' market channel for all three farms, despite the fact that the proportion of total sales derived from farmers' markets ranged from 19% for the large farm to 30% for the medium farm. Thus, a dollar of labor expense consistently generated the least amount of revenue in this channel. Most noticeably, the small farm's labor expenses comprised two-thirds of its farmers' markets revenues. Further investigation indicated that the small farm's labor hours for packing and storage activities related to farmers' markets exceeded those of the medium farm (although the medium farm's revenues in this channel were almost quadruple those of the small farm). The medium and large farms' labor/revenue ratios in farmers' markets leave significant margins to cover production costs and other expenses. The large farm's highly productive farmers' market program generated almost $4 in sales per dollar of labor expense.

As illustrated in Figure 1, expenses by marketing activity relative to revenues vary significantly by marketing channel for the farms, reflecting differences in the way product is packed, distributed and sold in each channel. In this paragraph, we discuss all marketing expenses 'as a proportion of total revenues in the marketing channel'—without repeating this phrase. In the wholesale channel, packing and storage costs are the highest expense category for all three farms. Selling and administration costs represent the highest expense category in both direct marketing channels for the small and medium farms. The small farm's high marketing costs in the farmers' market channel are very apparent. Since they are high for all three activities, this suggests that the small farm needs to seek ways to increase its sales at farmers' markets, such as by adjusting its pricing, choice of markets and/or merchandising practices.

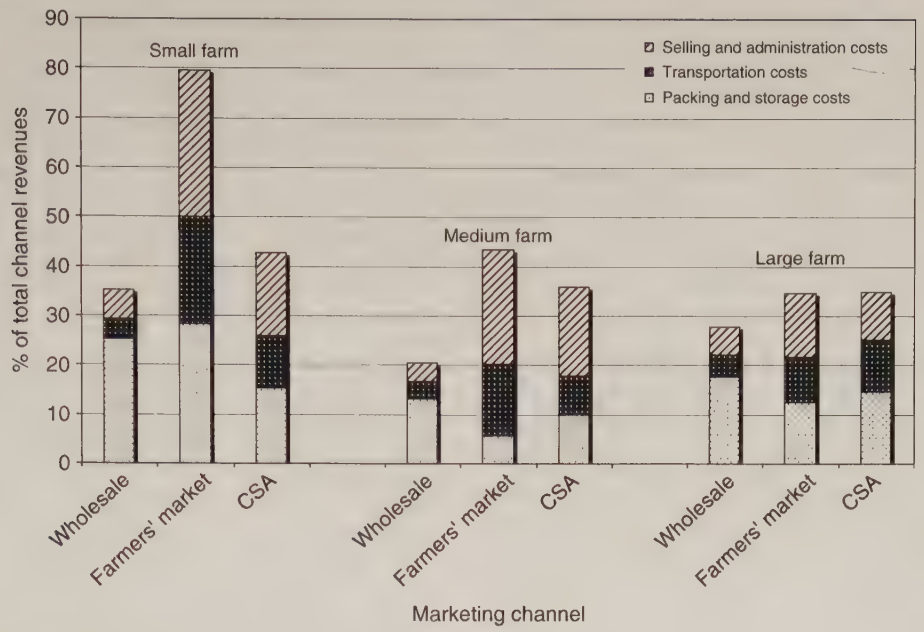

Figure 1. Marketing expenses by activity and marketing channel by farm.

Also, its packing costs in the wholesale and farmers' market channels are high compared to the other two farms. For the medium farm, transportation costs were highest in the farmers' market channel; this is not surprising since this operation sold at multiple farmers' markets. The large farm's marketing expenses are more evenly distributed and tend to be lower than those for the other two farms; this could be an indication that the large farm has stronger managerial expertise. Its highest expense category—packing and storage costs in the wholesale channel—is attributable to packing materials. Unlike the other two farms, the large farm sells in the wholesale marketing channel year-round (partially to maintain a continuous relationship with its customers); it packs the lower value winter crops and higher value summer crops in the same boxes for this market.

We define 'marketing cost rate' as total marketing costs divided by total channel revenues; it is displayed by marketing channel for each farm in Table 4. There is substantial variation across marketing channels and across the farms. Given the relatively higher selling and administration costs in the farmers' market channel, it is not surprising that the marketing cost rate was highest in this channel for both the small and medium farms and tied with the CSA channel as the highest for the large farm. For each farm, the marketing cost rate was lowest in the wholesale channel. These marketing cost rates are applied in the next section to assess the overall profitability of the different marketing channels.

We examined the data in Table 4 for evidence of economies of size in marketing costs. The large farm had the lowest overall marketing cost rate (30%), as well as for the farmers' market and CSA channels (both 35%). The medium farm had the lowest marketing cost rate in the wholesale channel (21%), although the large farm's wholesale revenues were more than 12 times higher. For the farmers' market channel, the large farm's higher sales volumes combined with its lower transportation costs and selling and administration costs, are possible indicators of economies of size; expenses for these categories are not affected much by sales volumes. The medium farm had the highest revenues for the CSA channel and its marketing cost rate in this channel was just one percentage point higher than that for the large farm. Relative to the other two marketing channels, the marketing cost rates for the CSA channel were remarkably similar, ranging from 35% for the large farm to 43% for the small farm. Variation in revenues across the farms was also the lowest for this channel; the medium farm's revenues were 123% higher than those of the small farm. Thus, there was no consistent evidence of economies of size in marketing costs across the marketing channels. Opportunities to achieve such economies were limited because there were few fixed costs involved with the marketing activities of these case-study farms. Economies of size are more likely to be observed in their production activities.

Table 4. Marketing costs as % of sales revenues by farm and channel.

	Marketing channel			
Farm	**All channels (%)**	**Wholesale (%)**	**Farmers' market (%)**	**CSA (%)**
Small	49	35	80	43
Medium	35	21	44	36
Large	30	28	35	35

Table 5. Net return per dollar of sales by farm and channel.

Farm	Marketing channel			
	All channels	Wholesale	Farmers' markets	CSA
Small	$0.51	$0.65	$0.20	$0.57
Medium	$0.65	$0.79	$0.56	$0.64
Large	$0.70	$0.72	$0.65	$0.65

Although the marketing cost rates summarize the results of our extensive data collection efforts, we found it even more meaningful to calculate net returns to marketing by channel by subtracting the marketing cost rates displayed in Table 4 from 1 (Table 5). These values represent the amount each farm netted to cover its production and overhead costs from each dollar of sales in a marketing channel after marketing expenses. For each farm, the net return to marketing was highest in the wholesale channel, ranging from $0.65 for the small farm to $0.79 for the large farm. A noticeable difference was that while the medium and large farms had $0.56 and $0.65, respectively, of each sales dollar from farmers' markets to cover their production and overhead costs, the small farm netted only $0.20 from every dollar of sales at farmers' markets after marketing expenses.

Profitability

While the net return rates discussed above are insightful, they are not the final indicator of the profitability of a marketing channel. Profit is defined as gross revenues minus costs. We did not collect data related to production costs for the three farms. However, recall that we considered crop production costs to be independent of the choice of marketing channel. When we discussed pricing with the operators of our case-study farms, they used prices in the wholesale channel as the reference point for their pricing in their direct marketing channels. Thus, we measure production costs (including overhead expenses not related to marketing) in terms of per dollar of sales in the wholesale market (represented as C). Let B_i be the average price mark-up rate in marketing channel i relative to the wholesale channel; thus, the production cost per dollar of revenue through channel i is (C/B_i) and B_i is 1 for the wholesale channel. The marketing cost rates we reported in Table 4 are stated in terms of per dollar of sales; the marketing cost rate for channel i is M_i. Thus, profit per dollar of revenue in marketing channel i, π_i, can be stated as:

$$\pi_i = 1-(C/B_i)-M_i. \quad (1)$$

With these values known, a producer can determine which marketing channel is most profitable.

The marginal effect of a change in the production cost (C) on profit in the different marketing channels is derived by differentiating Equation 1 with respect to C; it is $-1/B_i$. A simple sensitivity analysis is displayed in Table 6 for the medium farm, to demonstrate these results. The mark-up rate of 2.0 was used for both the farmers' market and CSA channels to reflect the medium farm's actual pricing practices, along with the marketing cost rates displayed for the medium farm in Table 4. While each $0.10 increase in C has a full $0.10 impact on profits in the wholesale channel, the impact in the farmers' market and CSA channels is only $0.05. The results in Table 6 demonstrate that changes in production costs affect the relative profitability of the marketing channels. Since the marketing costs were measured for a given set of prices, these prices cannot be changed. While the wholesale channel is the most profitable when production costs are low, the CSA channel becomes the most profitable when C reaches $0.40. The CSA channel is always more profitable than the farmers' market channel since there was an $0.08 spread in the medium farm's marketing cost rates between these channels while its mark-up rates were identical in these channels.

Table 6. Profit per dollar of revenue by cost of production and marketing channel, medium farm.[1]

Cost of production (C)	Wholesale	Farmers' market	CSA
$0.10	$0.69	$0.51	$0.59
$0.20	$0.59	$0.46	$0.54
$0.30	$0.49	$0.41	$0.49
$0.40	$0.39	$0.36	$0.44
$0.50	$0.29	$0.31	$0.39
$0.60	$0.19	$0.26	$0.34
$0.70	$0.09	$0.21	$0.29
$0.80	−$0.01	$0.16	$0.24
$0.90	−$0.11	$0.11	$0.19

[1] When B_{FM} and $B_{CSA} = 2.0$ and marketing cost rates as displayed in Table 4.

From this rather simplistic analysis, we could conclude that producers need to simply measure their marketing costs, calculate their profitability in each marketing channel and then market exclusively in the highest profit channel. However, there are factors in addition to production and marketing costs and mark-up rates needing to be considered when making marketing channels choices; they are discussed below.

Other Considerations in Selecting Marketing Channels

The producers of our case-study farms mentioned two important factors related to produce marketing that were not considered in these profit calculations—'sort-outs' and unpaid product. 'Sort-outs' relate to the fact that produce sold through the wholesale channel must meet USDA pack and grade standards while the produce that is too ripe and/or irregularly shaped or is otherwise 'cosmetically challenged' can still be sold through direct marketing

Table 7. Profit from 100 pounds of tomatoes in alternative scenarios.

Scenario	Revenue	Marketing expenses	Production costs	Profit
1. Wholesale	$100.00	$21.00	$70.00	$9.00
2. Farmers' market	$200.00	$88.00	$70.00	$42.00
3. Wholesale with 33% sort-outs	$67.00	$14.07	$70.00	−$17.07
4. Wholesale with 33% sort-outs and farmers' market for sort-outs	$111.22	$33.43	$70.00	$7.79
5. Farmers' market with 20% unpaid product	$160.00	$70.40	$70.00	$19.60
6. Scenario 4 and 20% unpaid product at farmers' market	$102.38	$29.56	$70.00	$2.82

channels. The large farm (which had 70% of its sales through the wholesale channel) estimated that approximately one-third of the produce harvested for its wholesale customers was 'sorted-out' and that about two-thirds of the sorted-out volume is subsequently sold through direct marketing channels. The production cost, *C*, includes the cost of producing the sorted-out volume. If some or all of the sorted-out product from the wholesale channel is sold in a direct marketing channel, then our profit calculations in Table 6 double-count the production costs for the sorted-out product. Given the large farm's 33% sort-out rate and its 67% diversion rate, the cost of production is overstated by 33%; alternatively, we could have modeled the sold sorted-out product as a by-product. Thus, profit rates are actually higher than indicated in Table 6 *if* the sorted-out product is sold through other channels.

Conversely, incorporating unpaid product decreases profitability. Unpaid product is product that is shipped into a particular marketing channel but does not generate revenue. The operators of the case-study identified four primary sources of unpaid product:

- deliveries rejected by wholesale customers;
- product used for sampling, customer bonuses and rounding-down weights at farmers' markets;
- product not sold at farmers' markets because of lack of demand (such as bad weather) or use of a marketing strategy of keeping the display tables full until the end of the market day and then donating this product at the end of the market day; and
- free boxes of product provided as compensation to hosts for CSA deliveries.

Six simple scenarios demonstrate how sort-outs and unpaid product can impact profits across channels. Assume that a producer harvests 100 pounds of tomatoes from a plot and the production and overhead costs (*C*) totaled $70. The tomatoes can be sold in the wholesale channel for $1.00 per pound or at the farmers' market for $2.00 per pound. The medium farm's marketing cost rates are included in all scenarios (21% of revenues in the wholesale channel and 44% of gross revenues for farmers' markets). The farm sells all of the tomatoes in the wholesale market in Scenario 1 and at the farmers' market in Scenario 2. Scenario 3 is identical to Scenario 1 except that the farm has a 33% sort-out rate in the wholesale market. Scenario 4 builds on Scenario 3; two-thirds of the product sorted out from the wholesale market is sold at the farmers' markets. In Scenario 5, the tomatoes are sold only at the farmers' market, with 20% of the volume unpaid due to sampling, rounding down of sales weights and end-of-market day donations. Scenario 6 is the same as Scenario 4, but it also includes 20% unpaid volume at the farmers' market. The sorted-out product could also be marketed through the CSA channel, or a combination of the farmers' market and CSA channels.

Scenarios 1 and 2 are the simplest scenarios; Scenario 2 has the highest profit (Table 7). Scenarios 3 through 6 reflect the effects of sort-outs and unpaid product, with profit lowest in Scenario 3 due to the absence of marketing of the sorted-out product from the wholesale market. Marketing the sorted-out product through the farmers' market allows the farm to reverse the financial outcome from a loss of $17.07 (Scenario 3) to a profit of $7.79 (Scenario 4); however, factoring in a 20% unpaid product rate for the farmers' market volume reduces the profit by two-thirds to $2.82 (Scenario 6). Comparing Scenarios 2 and 5 demonstrates the impact of unpaid product at farmers' markets—a 53% decrease in profit.

Clearly, using other values for the cost of production and sort-out and unpaid product rates would alter these results. But the primary message of these scenarios remains the same: marketing expenses, sort-outs and unpaid product can have a significant impact on a producer's profit. These factors need to be considered by producers when making marketing decisions and producers must monitor these factors closely. As producers gain experience in direct marketing, they may seek out ways to reduce their marketing costs, such as by choosing to not sell at distant farmers' markets with relatively low sales volumes. The 'naive' expectation of selling 100 pounds of tomatoes at a farmers' market for $130 in profit ($200 less $70 of production and overhead expenses) drops dramatically to $19.60 in profit when faced with the realities of costs for marketing and unpaid product. Additionally, marketing jointly in the wholesale and farmers' marketing channels (and perhaps even adding the CSA channel or a farm stand) can generate higher profits than farmers' markets alone.

Conclusions

Using a case-study approach, we developed a structure to measure and compare the relative marketing costs and profitability of different marketing channels that smaller

producers often participate in. We classified various marketing-related activities into three categories: packing and storage, transportation, and selling and administration. By measuring the costs for labor, purchased goods and services, and capital assets associated with these marketing-related activities, we determined that there are significant variations in marketing costs across marketing channels. For each of our three case-study farms, the marketing cost rate was lowest in the wholesale channel and highest in the farmers' market channel. Significant labor costs for the selling activity and transportation expenses can offset the higher prices and minimal packaging costs associated with farmers' markets.

LeRoux et al.[12] also compared ratios of marketing labor to revenue across channels. They determined that farmers' markets and staffed u-pick channels had the highest labor/revenue ratios, with the wholesale channel's ratio as average and the CSA channel's as the lowest. Our higher labor/revenue ratios in the CSA channels are likely to be attributable to the greater amount of customer service that our case-study growers provided to their CSA customers. LeRoux et al. determined that, as a group, CSAs generated a 87% net return per dollar of sales, compared to 67% for farmers' markets and 58% for wholesale. The wholesale channel generated the highest net returns in our case studies (between 65 and 72% per dollar of sales), while the CSA returns ranged between 57 and 65% and farmers' markets had the lowest returns (between 20 and 65%). Our generally lower net return rates are attributable to the fact that we included a wider range of marketing costs, such as depreciation and packaging materials; as previously noted, labor costs for our large farm represented just half (51.4%) of the operation's total marketing expenses. Furthermore, our case-study farms had higher transportation costs for their CSAs because they had multiple pick-up points, unlike the New York case-study farms. We also expect that, due to their proximity to the San Francisco Bay Area where there is high interest in locally grown foods, our case-study operations earned higher wholesale prices than their counterparts in central New York.

Our simplistic sensitivity analysis of the medium farm's profit rate for varying costs of production indicated that profitability was highest in the CSA channel and lowest in the wholesale channel, except when the cost of production was very low. Production costs were not incorporated into the LeRoux et al. analysis. We were unsuccessful in identifying other studies to compare with for our profitability analysis. The University of California's Cost and Returns studies calculate returns for a specific crop, rather than determining whole-farm profitability across different market channels; they are based on a hypothetical operation representing a composite of several farms. USDA's Census of Agriculture reports the number of farms by net cash farm income categories (losses, as well as gains) within the major crop/ranch classifications; however, these data are not tabulated by gross revenue levels or rates of return. USDA included questions related to the distribution of sales across the different channels in one of its 2008 ARMS surveys; however, there has been no public release of these data. Furthermore, the survey could not be used to calculate returns across different marketing channels because no data were collected regarding marketing costs.

The purpose of our sensitivity analysis was to demonstrate how profits can be significantly affected by sort-outs and unpaid product, as well as by marketing costs. The point of examining the different scenarios was not to develop absolute estimates of profitability; rather, we sought to examine how incorporating the particular conditions present in specific marketing channels impacted the channels' relative profitability.

The fact that marketing costs in the CSA channel were lower than those in the farmers' market channel for all three of our case-study farms (as well in the LeRoux et al. analysis) warrants further exploration. CSAs are appealing to producers because, once established, they often generate steady cash flow year-round with substantially less sales effort than selling at farmers' markets. Also, as noted by LeRoux et al., the CSA model is a lower risk method of marketing than farmers' markets, where a market day's sales potential can be adversely affected by adverse weather conditions, holidays and other factors beyond the producer's control.

The challenge is to find ways to expand CSA sales. Recent studies by Perez et al.[13] and Oberholtzer[14] indicate that there are two major attributes of CSA programs constraining their growth—product quantity and product choice. Some producers have developed hybrid forms of CSAs; for example, some CSAs offer different sizes of boxes and/or every other week deliveries to appeal to smaller households. To diversify their product selection, some producers exchange products with other local producers. The Pike Place Market Basket CSA contracted with approximately three dozen farms to offer boxes with a diverse product mix for its nearly 800 members[15]; the affiliated farmers had lower administrative and transportation costs than if they operated their own CSA.

The farmers' market channel is attractive to new producers because it has relatively few barriers to entry[16] as well as offering the potential to earn 'full retail. Farmers can enter this channel with minimal investment in packaging and other marketing materials; however, popular markets often have waiting lists for stalls. Farmers' markets can also provide significant networking benefits for new producers. Specifically, Feenstra and Lewis[17] determined that farmers' markets are a venue for developing entrepreneurial skills, providing producers with a venue for exchanging production and pricing information and networking among themselves. Additionally, farmers' markets can enable producers to develop relationships to enter new marketing channels; farmers can use their presence at a farmers' market to develop future CSA, restaurant and small wholesale customers. The manager of a large farmers' market association recently commented '... many of the bigger and more successful growers in farmers'

markets are no longer retail stalls, but showcases at a food show ... for restaurateurs and specialty buyers'[4]. Farmers' markets can also give producers a revenue stream while they are expanding their farming operations, such as developing the broader product line they need for a successful CSA program and/or increasing their production volumes to be large enough to sell to wholesale customers.

Direct marketing channels can provide several other benefits to producers. Market diversification is a classic risk-spreading tool in all industries, including agriculture. Direct marketing increases the number of marketing options available to farmers. For example, when prices in the wholesale market for heirloom tomatoes are low due to excess supplies, producers can still receive 'full retail' prices for their tomatoes at farmers' markets. Another benefit of direct marketing is that the industrialized US food distribution system, including the consolidated chain structures within the grocery and food service segments, is designed to handle high volumes of uniform product at low cost, and most shelf-stable processed foods are well suited for such markets. However, the requirement of a high volume of uniform product effectively eliminated the market for produce varieties with relatively short shelf lives and/or those prone to irregular shapes. Direct marketing channels can give farmers' markets power by enabling them to differentiate their produce from that marketed through the traditional produce distribution system. Farmers can market heirloom varieties of produce that cannot withstand a lengthy marketing period; consumers are attracted to these flavorful varieties[18]. Additionally, many consumers purchase directly from producers because they want information about the practices used to produce the food they consume and they are able to discuss such matters with producers at farmers' markets and other direct marketing venues. Related to this, farmers are able to retain their identity as the producer when they market directly.

The producers in our case studies all commented about the flexibility they have by selling in three marketing channels; such diversification reduces their marketing risk. In addition to having a market for 'cosmetically challenged' produce in direct marketing channels, they can market produce that is in excess supply in the wholesale market through farmers' markets and CSAs. Conversely, they can also use the direct marketing channels to sell crops at the beginning and end of the harvest season that are often too small in volume to be handled efficiently through the wholesale channel.

Direct marketing complements, rather than displaces, the traditional wholesale produce distribution system in the United States. Packers, distributors, grocery chains and other downstream entities involved in the traditional US food distribution system incur costs as they provide services, such as sorting, storage, transportation, promotion and selling, to move produce from growers to consumers. Our research demonstrates that the price premiums that farmers earn by direct marketing rather than wholesaling are not pure profit; the higher prices are compensation for the costs they incur when direct marketing their produce. Smaller farmers can build financially viable operations using direct marketing channels to obtain access to markets, grow their farming operations, reduce their marketing risk, and gain market power by providing consumers products with attributes that are not readily available in the industrialized produce distribution system. However, to achieve this success, they must manage their marketing costs as well as their production costs.

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A contingent valuation analysis to determine profitability of establishing local organic wine markets in Spain

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Abstract

In this research an alternative is proposed for viticulture producers that would allow them to maintain their income and prevent the abandonment of their agricultural activity. The proposed alternative is the production of organic wine with subsequent commercialization in the local market. The suitability of the alternative is measured by the acceptance of the product in local markets. This acceptance was determined through contingent valuation, which relates probability of purchase to willingness to pay (WTP). Since regional differences could exist for product acceptance, the preliminary hypothesis was formulated that the importance of the viticulture sector in the regional economy makes consumers value farm work more highly and pay more for sustainable agricultural practices. Two regions of Spain were taken into consideration because of the different weight of their agricultural activity: Castile-La Mancha and the Community of Valencia. A survey of 800 wine consumers was made (400 from each region) to determine WTP. From the results it was shown on the one hand that organizing organic wine in local markets can be a profitable alternative for wine producers and, on the other hand, consumers from regions where wine production shares a larger proportion of the regional economy are willing to pay more for organic wine.

Key words: organic wine, willingness to pay, contingent valuation, regional differences, local markets

Introduction

The rural areas of Europe represent 91% of the territory in the EU-27, with about 56% of the population living in them. Rural areas generate 45% of the gross value added in the EU-27 and 53% of the employment[1]. These indices adequately justify the importance of rural development.

In some countries, the rural sector has undergone an important quantitative loss. Concretely in Spain, in the past 40 years, the population of towns with less than 10,000 inhabitants was reduced from 57% of the Spanish population to only 23%. Meanwhile rural surface area covers more than 80.2% of the total surface area. These data alone are important enough to justify the study and development of a Rural Development Policy at more detailed levels[2].

The environmental, cultural, social and economic relevance of agricultural activity in rural surroundings is indubitable. Nevertheless, in the past few decades the agricultural sector has lost its importance in the economy.

Abandonment of agricultural activity causes diverse problems: (1) environmental, since abandoning fields is one of the chief causes for the advance of desertification; (2) cultural, associated with the knowledge of the cultivation of these lands and the species grown on them, including the combination of ideas, beliefs and symbols that define in cultural terms the specific systematic relationships between local communities and their environmental surroundings; (3) social and (4) economic, since the cyclic renovation of the wealth produced by agriculture disappears when the land is dedicated to other activities such as construction. The economic circuit is reduced to the process of buying, constructing and selling property, and stops there, reducing new forms of producing wealth[3,4].

In order to prevent some of these effects, the development of rural areas is being promoted. In many cases, however, the consequence of the means that are being used is the relative decrease in the weight of agriculture in the economic system. Non agricultural activities are

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Table 1. Agricultural economic indicators from Castile-La Mancha and Community of Valencia, 2006.

Agricultural economic indicators	Castile-La Mancha	Community of Valencia
GDP[1] (volume)	€2608.1 million	€1979.0 million
GDP (%)	7.7%	2.1%
GDP evolution (2000–2006)	5.6%	0.9%
Employment (volume)	58,300	78,200
Employment (% region)	7.3%	3.6%
Wine production (volume)	€605.3 million	€54.9 million
Wine (% agricultural GRP[2])	17.3%	2.1%

[1] GDP: gross domestic product.
[2] GRP: gross regional product.
Source:[18–21].

increasing, such as crafts, recreation and tourism, which do not contribute to solving of the above-mentioned problems[5].

Therefore, contributing solutions permitting farmers to maintain their income and avoid the abandonment of their activity is vitally important. The maintenance of agricultural surface areas within the ambit of good agricultural and environmental conditions has become a priority issue for the Ministry of Agriculture, Fisheries and Food[2]. One of the solutions that could be suggested in this context is organic production.

However, the consumption of organic food is not very well established, especially in southern European countries, where there has been a very important increase in this type of production in recent years[6]. Competition from lower-priced products coming from Third World countries and the higher prices obtained abroad make this market seem a priori unattractive to producers.

All the same, many advantages exist: (1) the consumer is closer, so fewer intermediaries would be needed to get to market and producers could have greater control over the product[7–10]; (2) the local market could include social and economic advantages for producers and for the society in general, since local production creates jobs and produces wealth[9,11,12]; (3) the local market is a more environment-friendly alternative, since contamination from transportation is decreased[13–15]. Therefore, this alternative is expected to imply economic, environmental and social benefits to local areas by providing more sustainable consumption patterns.

There is tremendous potential for local marketing of farm products, but there is a gap between consumers, demand and willingness of farmers to meet this demand[16]. The type of products, their method of delivery and pricing are important issues that have to be considered in this market choice[17].

This study investigates organic production destined for local markets as an environment-friendly, potentially profitable alternative for farmers. To establish whether the proposed alternative is adequate, the willingness of consumers from these markets to pay was analysed. If the increase in price that consumers are willing to pay for the organic product surpasses the higher cost of organic production, the alternative could be considered economically viable and might be an agricultural 'solution' to prevent the abandonment of farm land.

This research center on a product of great importance in Europe, i.e., wine. Currently, the EU has over 2.4 million wine-producing enterprises cultivating 3.6 million hectares, equivalent to 2% of the EU agricultural surface area. Viticulture production in 2006 represented more than 5% of the EU agricultural production value, but wine consumption in the Union is in constant decline. Relevance of the sector in Spain is amply contrasted, since it is the leading country in the world in surface area dedicated to vineyards (1,135,000 ha), and the third in production (38.9 million hl)[18]. Wine and grape juice (must) production in Spain entailed €969.4 million in 2005, which represented 2.4% of the total gross agricultural output and 3.9% of the value from plant production[19]. Besides, in Spain, vineyards are the third crop with regard to surface area, after cereals and olive groves.

The viticulture sector in the economies of Castile-La Mancha and the Community of Valencia

This research was carried out in two Spanish regions (Castile-La Mancha and the Community of Valencia) where the agricultural sector has decreased significantly in recent years.

Castile-La Mancha is an interior region, located in the south-central part of Spain. The Community of Valencia is an area on the Spanish Mediterranean coast. Some agricultural economic data are shown in Table 1.

In view of the economic data, it seems obvious that the relative importance of the agricultural sector is greater in Castile-La Mancha than in the Community of Valencia. The importance of vineyards in terms of covered area and production is also greater in Castile-La Mancha than in the Community of Valencia.

Thus, Castile-La Mancha has 553,000 ha of vineyards, which is 47.6% of the national area cultivated with vineyards, and produces 17.7 million hl of wine, 48.6% of the total national production, while vineyards in the Community of Valencia extend over 86,161 ha, which is

7.4% of the total national area cultivated with vineyards, and production is 2.4 million hl, which is 6.7% of the total national wine production[18].

Organic wine

This alternative is compatible with the new tendencies in food production associated with a higher awareness of consumers with regard to health and respect for the environment[22–24].

There seems to be a consensus in which the consumer perceives organic products as *greater in quality and healthier* as well as *more respectful of the environment*[25–27]. Nevertheless, one of the greatest disadvantages of these products is their higher price due to greater production costs and to inadequate distribution[28,29].

Production costs of organic products in Spain are estimated to be, in general, about 22% higher than for the traditional products[30].

In the particular case of organic grapevine, it's estimated that production cost is about 20–25% higher than the cost of traditional grapevine crops, basically due to a 50–60% increase of labor cost.

For this reason farmers could make their production profitable if consumers would be willing to pay a percentage for organic wine similar to the increase in production costs for that wine. The price of a new organic wine destined for the local market is estimated to be 25% higher in price than traditionally produced wines.

Thus, determination of the increase in price that consumers are willing to pay would allow the estimation of whether the product could be profitable for wine producers. Whether wine consumers are willing to pay (or not) a surcharge for an organic wine with regard to a similar conventional wine should be determined. Then the percentage of increase would be established and the characteristics permitting the differentiation of potential organic wine consumers. All these determinations would be carried out by considering consumers from two regions where the degree of influence from the viticulture sector on the regional economy is different.

Starting from the above objectives, the following hypotheses were proposed for this study:

Hypothesis I: Organic wine production is a viable alternative in local markets.

Hypothesis II: The importance of the wine production sector on local economies is proportional to the willingness of consumers to pay more for organic wine.

Methodology

To determine the acceptance of an organic wine, the contingent valuation method (CVM) was used, which concretely measures consumer willingness to pay (WTP) for a certain product.

Traditionally, this method is used for goods that do not have a certain market and its applications to environmental valuation are considered[31]. The technique has been extended to other areas, the industrial and agro-food sectors being noteworthy.

Within the agro-food sector, the CVM has been applied to research relative to food safety, with the purpose of estimating WTP to prevent the potential risk involved in the consumption of a determined food[32–34].

The applications of the CVM to agro-food marketing are also important[35] in analyzing, the purchasing behaviour of individuals in retail food establishments. Other authors have used it to determine explanatory factors in meat consumption[36] and others to determine increases that consumers would pay for fair trade foods[37].

This method has been used previously in the concrete case of organic products. The analysis evolved from the first estimations of WTP for a residue-free product[38–40], taken up again later to estimate whether this type of product was dealt with as 'safer'[41] even though it did not represent a specific reduction in food risk[42]. Economic compensations have also been established for organic producers according to the level of damage appearing in the product[43]. In other studies WTP has been consistently detected for a significantly superior product by a segment of consumers more sensitized to environmental issues who rate themselves as regular purchasers of these products[44–46]. In the case of organic wine, this methodology has been used to evaluate wine preferences in consumers from Colorado (USA)[47].

Due to previous research, the CVM is sufficiently tested to allow the determination of whether consumers are willing to pay an increase in price that at least compensates for the extra cost of producing organic wine.

The CVM is based on a survey that establishes a hypothetical market situation where the offer is personified by the pollster and demand by the surveyee in such a way that the pollster tries to get the highest price that the surveyee is willing to pay for the good in question[48].

To this end, a survey was made of wine consumers in the Community of Castile-La Mancha and the Community of Valencia (questionnaire in the Appendix). The survey was carried out during March 2007, by four properly trained pollsters. The total number of surveys was 800, half from Castile-La Mancha and is their higher price half from the Community of Valencia. For the sample design, population data was used from the 2006 National Statistics Institute[19]. Sampling was random and stratified with proportional adjustment to gender and age (18–29 years old, 30–49, 50–64 and over 64). Persons who were about to buy food for home consumption in stores, supermarkets and hypermarkets were surveyed, for a level of error equal to 5% and a 95.5% level of confidence ($P = Q = 0.5$; $k = 2$).

Besides the queries in the questionnaire that allowed the determination of WTP, others were included to characterize the organic wine consumer. These questions related to wine consumption and knowledge, and the consumption of

Table 2. Percentage of consumers who were willing to pay a specific premium price for an organic wine.

Premium price**	Total (%)	Castile-La Mancha (%)	Community of Valencia (%)
Would not pay a premium price	24.2	27.5	19.7
Less than 25%	37.6	27.3	51.5
25–49%	21.3	23.3	18.7
50–99%	12.2	16.0	7.0
More than or equal to 100%	4.7	6.0	3.0

** $P < 0.01$ between the two sites.

organic products, as well as to surveyee lifestyle and socio-economic characteristics.

In the concrete case of questions relative to the determination of WTP, the mixed question format with a reference price was used. This is the most extensive format in studies that apply contingent valuation to marketing.

Thus, two consecutive questions were included: the first was a dichotomy where surveyees only answered whether they were willing to pay a determined increase in price or not. The second was an open question where they indicated the maximum increase in price that they would be willing to pay for organic wine compared to traditional wine.

This question format permits the acquisition of more reliable, disperse values but can introduce a warp in the guide price[48]. To prevent that, the sample was divided into four sub-samples. In each one, the first question of the CVM indicated a different starting increase in price (10, 25, 50 and 100%), above a reference price of 2 € per 0.75 litre bottle, an average sale price for young wine of a quality obtained through visual inspection by researchers in the establishments where the surveys were made.

To obtain the results for WTP, first a descriptive statistical analysis was used as an open question for both regions, and the averages obtained were compared in each case through analysis of variance (ANOVA).

Then a logistic regression was used (Eqn 1), with the answer to the closed question as the dependent variable. (Would they pay an increase in price for an organic wine or not?) Independent variables were the questioned increase and surveyee region of origin.

$$P = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_1 X_2)}} \quad (1)$$

P: probability of paying (it takes on the value of 0 if the consumer is not willing to pay a determined increase in price and of 1 on the contrary).

β_0, β_1, β_2, β_3: coefficients of the equation.

X_1: percentage of price increase for organic wine.

X_2: the surveyee's region of origin (it takes on the value of 0 if the wine consumer is a resident of Castile-La Mancha and the value of 1 if from the Community of Valencia).

Through a simple transformation and under the hypothesis that the function of individual utility is linear, the average and the median of WTP coincide. So the average WTP can be calculated as a mathematical expression by using regression coefficients[49], as shown in Equation 2.

$$E(\mathrm{WTP}) = \int_0^{\infty} \frac{1}{1 + e^{-(\beta_0 + \beta_i X_i)}} \delta X = -\frac{\beta_0}{\beta_i}. \quad (2)$$

Results

Consumer acceptance of an organic wine

In the first place, the percentage of consumers who would pay more for organic wine than a traditional wine was determined. In this way the size of the potential market for this product was established among consumers that perceive greater utility from the organic product. Then the concrete value of the organic product was quantified.

From the obtained data, a large percentage of consumers were found who would pay more for an organic wine, with a significantly greater percentage of these consumers in the Community of Valencia (80.2%) than in Castile-La Mancha (72.6%), since significant differences start at 1%.

Then only those consumers were focused on who would pay the increase in price that guarantees product profitability to compensate the higher production cost of organic wine (around 25% higher). In Castile-La Mancha, 45.3% of these consumers would pay more than a 25% increase in price while this percentage would be 28.7% in the Community of Valencia (Table 2).

The average estimated premium price that consumers from Castile-La Mancha would pay for organic wine was 58.4% (€3.2) while those from the Community of Valencia would pay 16.3% (€2.3) (Table 3).

Once it was established that consumers were interested in the product, potential consumers from each region were characterized. Differences were also established of those who were not willing to pay the price increase that cultivating these products entails.

Characterization of organic wine consumers

To try to explain regional differences in WTP, consumers from both geographical areas were characterized according to their lifestyles, socio-economic characteristics and level of knowledge about organic food.

To determine the variables relative to organic wine consumer lifestyles, a preliminary factorial analysis was

Table 3. Maximum surcharge price (direct determination and logistic model) and variables obtained from the logistic model[2] for organic wine.

Maximum premium price			**Castile-La Mancha**		**Community of Valencian**	
WTP (direct estimation)*			22.7% (2.5€)		16.7% (2.3€)	
WTP Log. Reg. (equation 2)			58.4% (3.2€)		16.3% (2.3€)	
Variables	β	SE	Wald	df	Sig.	Exp(β)
Surcharge	−0.030	0.004	72.077	1	0.000	0.970
Region[1]	−0.694	0.334	4.320	1	0.038	0.500
Region × Surcharge	−0.035	0.011	10.912	1	0.001	0.966
Constant	1.753	0.202	75.508	1	0.000	5.771

* Indicate the existence of significant differences for a maximum error level of 5%.
[1] Dummy variable (1: Comunidad Valenciana consumers and 0: Castile-La Mancha consumers).
[2] −2LL decrease (963 to 722), R^2 Cox and Snell: 0.292 and R^2 Nagelkerke: 0.390. Chi-squared in the Hosmer and Lemeshow test is not significant. 75.3% of the cases are classified correctly.

Table 4. Analysis of rotated factor matrix for consumer lifestyles.

Consumer lifestyle	**Mean***	**Standard deviation**	**Factor 1 food**	**Factor 2 environment**	**Factor 3 health**
I eat red meat in moderation	3.45	±1.340	0.788	−0.048	−0.031
I try to eat food without artificial additives	3.13	±1.435	0.711	0.258	0.122
I eat fruits and vegetables often	4.20	±1.136	0.541	−0.004	0.426
I belong to an association to defend nature	1.31	±0.879	−0.031	0.825	0.049
I contribute to non-profit organizations	1.81	±1.398	0.113	0.819	0.079
I exercise regularly	3.01	±1.524	−0.116	0.092	0.803
I voluntarily get periodic health check-ups	4.13	±0.995	0.389	−0.074	0.582
I eat a vegetarian diet	1.88	±1.223	0.199	0.345	0.493
Explained variance–factor (%)			20.5	19.4	17.9

Sample adequacy (Kaiser–Meyer–Olkin): 0.695.
Significance level of Bartlett roundness test: 0.000.
* Likert scale, from 1 (strongly disagree) to 5 (strongly agree).

made, a varimax rotation[50]. It allowed the information contained in a series of original variables to condense into a smaller series of composite dimensions (factors) with a minimum loss of information. Three factors were identified: one related with concern about food, another with concern for the environment and a third with concern for health. The total explained variance was 57.8% (Table 4).

Once the variables were identified that determined organic wine consumer lifestyles, their characterization was made in Castile-La Mancha as well as in the Community of Valencia, depending on whether or not they were willing to pay a minimum increase in price of 25% for an organic wine over a traditional one (Table 5).

Concerning the variables relative to lifestyles, in the Community of Valencia consumers were more concerned for the environment, as well as for health and for food, than in Castile-La Mancha.

In *concern for food,* two differentiated sub-groups were observed. The first, having a greater concern for food, included all the consumers from the Community of Valencia. All consumers from Castile-La Mancha were found in the second sub-group, as well as those from the Community of Valencia who would not pay a 25% price increase. The latter were included in both groups, since their concern for food was intermediate.

In the variable *concern for the environment*, three differentiated sub-groups appeared. In the first, consumers from the Community of Valencia were found who had a greater concern for the environment and were definitely willing to pay 25% more for organic products. In the second, consumers from the Community of Valencia were found who had an intermediate concern for the environment and would not pay a 25% increase in price. The third sub-group was formed by those consumers from Castile-La Mancha who do not seem to be greatly concerned about the environment.

Three sub-groups appeared in the *concern for health* variable. The first was formed by consumers from the Community of Valencia who would pay a 25% price increase for organic wine and who showed great concern for health. The second was formed by consumers from the Community of Valencia who would not pay 25% more and by those from Castile-La Mancha who would pay more. Their concern for health was intermediate. The third was formed by consumers from Castile-La Mancha who would not pay 25% more for organic wine and whose concern for health was low. It must be emphasized that for the majority of considered variables, greater differences seemed to exist between consumers when the region of origin was taken into account than when WTP the price

Table 5. Consumers characterization for market segments.

Feature	Levels	CLM[1] WTP[3] (45.3%)	No WTP (54.7%)	CV[2] WTP (28.7%)	No WTP (71.3%)
Consumer lifestyle**	Food	-0.137^{b}	-0.078^{b}	0.21^{a}	$0.085^{a,b}$
	Environment	-0.23^{c}	-0.30^{c}	0.57^{a}	0.20^{b}
	Health	$-0.06^{b,c}$	-0.30^{c}	0.41^{a}	$0.14^{a,b}$
Gender	Male	49.7%	50.2%	46.5%	47.9%
	Female	50.3%	49.8%	53.5%	52.1%
Age** (years)	18–29	35.4%	27.9%	25.4%	29.1%
	30–49	31.5%	20.1%	42.1%	39.4%
	50–64	15.5%	21.9%	17.5%	19.2%
	>64	17.7%	30.1%	14.9%	12.2%
Education**	Grade school	38.2%	54.9%	22.8%	27.7%
	High school	34.8%	26.5%	39.5%	39.4%
	College	27.0%	18.6%	37.7%	32.9%
Monthly family income (€)	<1000	19.4%	31.0%	21.1%	24.4%
	1001–1500	32.8%	26.2%	33.3%	36.2%
	1501–2000	26.7%	25.7%	24.6%	21.6%
	2001–3000	12.8%	11.9%	16.7%	12.7%
	>3000	8.3%	5.2%	4.4%	5.2%
Organic food knowledge**	Low	42.7%	2.8%	22.1%	3.3%
	Low-medium	28.2%	9.7%	24.4%	6.1%
	Medium	22.1%	30.1%	36.0%	25.6%
	Medium-high	4.2%	43.1%	14.0%	49.4%
	High	2.8%	14.4%	3.5%	15.6%

** Indicate the existence of significant differences for a maximum error level of 5%.
[a–c] Different letters indicate the existence of significant differences for a maximum error level of 5% (Tukey test).
[1] CLM: Castile-La Mancha.
[2] CV: Community of Valencia.
[3] WTP: willingness to pay.

increase that guarantees product profitability was considered.

Results from the socio-economic variables indicated that significant differences only appeared concerning educational level and age. It is noteworthy that in this case the most relevant differences appeared according to consumer region of origin. Concerning the educational level variable, in Castile-La Mancha there is a greater percentage of consumers with an elementary education and in the Community of Valencia a greater percentage of consumers have a higher education.

For the age variable, in Castile-La Mancha, there is a higher percentage over 64 years of age and in the Community of Valencia there is a greater percentage of consumers between 30 and 49 years old. Besides, in Castile-La Mancha, the older population is less willing to pay more for the organic product, which is not as evident in the Community of Valencia. Concerning gender and monthly family income variables, significant differences did not appear in consumer distribution.

Referring to knowledge about organic products, a true or false question was introduced into the questionnaire about the organic product concept. Consumers were asked to indicate which answers they thought were correct. According to the number of right and wrong answers given by consumers, a variable was created denominated *knowledge of organic products* with five levels: 1 for low and 5 for high. A five-point Likert scale was used for their level of agreement, with 1 point for total disagreement and 5 for complete agreement.

The results of this variable indicated that significant differences between consumers from both regions existed at 1%. The percentage of consumers having a low or medium-low level of knowledge concerning organic products was greater in the Community of Valencia than in Castile-La Mancha. This fact could be due to the greater importance of the agricultural sector in Castile-La Mancha, where the society in general might be more 'sensitized' to this sphere.

Discussion

Validity of the contingent valuation

In this study, based on contingent valuation, a logistic regression model was used to analyze data. The model related WTP a price increase for organic wine with two variables, surveyee region of origin and the percentage of price increase for organic wine compared to a similar traditional wine. The data used were adjusted to the model since chi-squared in the Hosmer and Lemeshow test was

not significant and 75.3% of the cases were classified correctly. Besides, the requisites were sufficiently fulfilled: −2LL decreased (from 963 to 722), the Cox and Snell $R^2 = 0.292$ and the Nagelkerke R^2 was 0.390.

The increase in price was the chief model predictor, as reported by others, but the region of origin was also significant[51,52]. As expected, the model indicated that the higher the increase in price for organic wine, the lower the probability of paying. In the proposed model, the relationship between belonging to a determined region and the probability of paying was also shown. When the respondent was from the Community of Valencia, the probability of paying was lower than from the region of Castile-La Mancha.

The other variables used in previous studies for predicting WTP for food[53,54], as well as socio-economic characteristics of the individuals and their lifestyles, were not significant for explaining WTP an increase in price for organic wine.

These results indicated in the first place that the increase in price of the product is very important for wine consumers when purchasing organic wine. The form of the function used indicated that at very high increases there would hardly be any consumers willing to buy the product. Therefore, in spite of the potentially very high profitability per product unit, the eventual income would be very small, because not much of the product would be sold.

In the second place, the influence of surveyee region on WTP makes it seem necessary to plan different commercial strategies for each market.

Implications

This research has some practical implications. Organic wine is suggested as an alternative for vine growers who have suffered important income losses in recent years. These income losses are basically due to growing competition in viticulture markets and the decrease in current consumption. The higher price that organic wine could reach in markets would amply compensate for the higher cost of this type of crop particularly due to lower productivity and the greater need for labor.

From the results of this study, it can be stated that:

Hypothesis I is accepted: '*Organic production is an adequate alternative for wines in local markets*' since more than 80% of consumers would consume organic wine. Besides, a high percentage of consumers would be willing to pay over 25% more for this type of wine: 45.3% of consumers in Castile-La Mancha and 28.7% in the Community of Valencia.

Hypothesis II is accepted: '*The importance of the wine production sector on local economies is proportional to the willingness of consumers to pay more for organic wine*'.

The average increase in price that consumers are willing to pay is especially high in Castile-La Mancha, a region where the agricultural sector is more important (7.4% of gross value added (GVA)) and where the weight of wine and grape juice (must) production is high in total gross agricultural output (22%). In this region, the increase in price is 58.4% (€3.2). In the Community of Valencia, where the weight of agriculture is lower (2.2% of GVA) and wine and must production is 3.3% of total gross agricultural output, the increase in price is 16.3% (€2.3).

Other variables were considered, such as educational level or concern for health, the environment and food, which might influence the acceptance of organic products. (In the Community of Valencia, the higher the educational level, the greater was the concern in all cases.) However, results did not allow for the establishment of a direct relationship between these variables and acceptance of organic products. Nevertheless, it seems important to establish information campaigns, since the level of knowledge about organic products was directly related to the acceptance of organic wine, especially in the Community of Valencia. Campaigns should be directed toward increasing knowledge about these products, which appeal to consumers concerned about health, the environment and food, since a priori they could be the first to adopt these products.

Limitations

The main limitation to this study is the method used. Contingent valuation belongs to the group of direct or hypothetical methods based on information furnished by individuals themselves when asked for their valuation of the object under analysis[55]. This method presents an important limitation, the so-called hypothetical warp, which establishes that, since the questions are hypothetical, the answers could also be hypothetical[56]. Previous studies indicate that demand is overestimated by hypothetical methods[57].

Nevertheless, the scarcity of a product at this time with these characteristics, an organic wine from each region, and the limited budget available for research has made the use of experimental methods difficult.

Finally, a classification of regions is lacking that would permit extrapolating the results and proposing similar commercialization strategies for each of the established types. This would also be useful for establishing the appropriateness in advance of an alternative strategy in a determined region to prevent futile efforts.

Conclusions

Progressive abandonment of farm land and the substitution of agriculture for other, basically urban, activities are facts that do not contribute to the sustainability of the planet. Therefore, the proposal of profitable alternatives for the agricultural sector is indispensable.

Besides being more environment-friendly (let us not forget *food miles*), the local market has frequently forgotten that such alternatives could be an attractive objective to viticulture growers, who could thus have greater control over their product in the presumably shorter distribution

channel. This study also established that the proposed alternative is valid in regions with different economic realities, since regions with differing weight in the agricultural sector were considered, even though the strategies to follow might be different according to the region under consideration.

The price increases that organic wine consumers would be willing to pay are high enough to compensate amply for the additional cost involved in producing this type of wine. Generally, over 80% of the consumers were willing to consume organic wine.

In any case, it seems important that businesses interested in this alternative should make the benefits known of organic production and particularly the consumption of organic wine. For greater knowledge is directly related to a greater increase in price.

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Appendix

Organic Wine Questionnaire

Good morning/good afternoon. Miguel Hernández University/Castile-La Mancha University* is making a survey about organic wine. You have been chosen at random and the survey is completely anonymous. It will take around 15 min to complete. Thank you for completing this survey.

1. Do you use wine at any time?

☐ Yes ☐ No (end of survey)

2. Could you indicate if you have consumed organic products? (If the answer is no, go to question 3.)

☐ No ☐ Yes, but I only tried them ☐ Yes, occasionally ☐ Yes, usually ☐ I don't know

3. Would you consume organic products?

☐ No, I don't consume and I wouldn't consume ☐ Yes, but it's unlikely ☐ Yes, it's quite likely ☐ Yes, it's very likely ☐ Yes, sure

4. Could you indicate which of these characteristics define organic products (please, tick as appropriate)

☐ Protect the environment
☐ Use organic material and natural fertilizer
☐ Have specific regulations
☐ Carry a certificate guaranteeing compliance to regulations
☐ Contain neither food preservatives nor dyes
☐ They are generated by traditional processes
☐ They have got a great flavour
☐ They are good for dieting

5. Do you consume organic wine?

☐ Yes ☐ No, Why? (Please, tick as appropriate).
- ☐ It's more expensive than conventional wine
- ☐ I do not think it's best
- ☐ It's not available in my place of purchase
- ☐ It is not sufficiently guaranteed
- ☐ The health benefits are questionable
- ☐ It is just a fad

6. Would you be willing to pay more (10 percent/25 percent/50 percent/100 percent*) for organic wine than conventional wine?

☐ Yes ☐ No

If your answer is 'no': how much more would pay for an organic wine? _____ percent.

7. Please indicate your level of agreement with the following statements about lifestyle (1 strongly disagree; 5 strongly agree).

☐ I voluntarily get periodic health check-ups
☐ I eat a vegetarian diet
☐ I exercise regularly
☐ I eat fruit and vegetables often
☐ I eat red meat in moderation
☐ I try to eat food without artificial additives
☐ I belong to an association to defend nature
☐ I contribute to non-profit organizations

8. Gender

☐ Male ☐ Female

9. Education

☐ Grade School ☐ High School ☐ College

10. Monthly Family Income (€):

☐ <€1000 ☐ €1001–€1500 ☐ €1500–€2000 ☐ €2001–€3000 ☐ >€3000

11. Age (years)

☐ 18–34 ☐ 35–49 ☐ 50–64 ☐ >64

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Vitamins A, E and fatty acid composition of the eggs of caged hens and pastured hens

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Abstract

In the US farmers often market pastured poultry eggs for a premium price, claiming animal and human health benefits. We examined how moving pastured hens to forage legumes or mixed grasses influenced hen (*Gallus gallus* L.) egg omega-3 fatty acids and concentrations of vitamins A and E. We also compared the eggs of the pastured hens to those of hens fed a commercial diet in cages. We used a cross-over design to compare pasture species: 75 sister hens were assigned to one of three pasture treatment groups: (1) alfalfa (*Medicago sativa* L.), (2) red and white clover (*Trifolium pretense* L. and *Trifolium repens* L.) or (3) mixed cool season grasses. Groups were rotated to all three pasture treatments, each for 2 weeks and supplemented with 70 g commercial hen mash bird^{-1} day^{-1}. Pasture botanical composition, forage mass, leaf to total ratio and plant fatty acid composition were compared among pasture treatments. Eggs of the pastured hens were compared to eggs of 50 sister hens that were fed only commercial hen mash in cages for the entire 6 weeks. Forage parameters varied somewhat, but did not explain plant linolenic acid variation. Seventeen of the 18 quantified egg fatty acids, and vitamin A concentrations did not ($P < 0.05$) differ among the three pasture treatment groups. Eggs of the hens that foraged grasses had 23% more ($P < 0.0001$) vitamin E than eggs of hens that foraged clover. Compared to eggs of the caged hens, pastured hens' eggs had twice as much vitamin E and long-chain omega-3 fats, 2.5-fold more total omega-3 fatty acids, and less than half the ratio of omega-6:omega-3 fatty acids ($P < 0.0001$). Vitamin A concentration was 38% higher ($P < 0.05$) in the pastured hens' eggs than in the caged hens' eggs, but total vitamin A per egg did not differ. At the end of the experiment, pastured hens weighed 14% less and averaged 15% lower hen-day egg production than caged birds ($P < 0.0001$). Results suggest that grass pastures may enhance vitamin E in eggs of pastured hens more than clover, and pastured hens supplemented with commercial mash will produce eggs with significantly more vitamin E and total omega-3 fatty acids compared to eggs from caged hens fed only commercial hen mash. Pastured hens may have lower body weight and egg production than caged hens, unless they are supplemented adequately to meet their dietary energy and crude protein needs.

Key words: omega-3 fat, pastured poultry, vitamin A, vitamin E, poultry eggs, pasture, legumes

Introduction

Producing poultry on pasture or cover crops is becoming a popular way for livestock and crop farmers to diversify their operations in the United States[1]. Poultry are often rotated onto pastures after cattle or sheep, where they forage on regrowth and scavenge for invertebrates in manure deposits often helping to distribute manure nutrients. Recent research indicates that livestock products from animals that forage grasslands have a higher concentration of omega-3 fatty acids and fat-soluble vitamins than livestock products from animals that are fed grain and stored feed diets[2–5].

The chicken has a short digestive tract and can rapidly assimilate dietary nutrients. Fat-soluble vitamins in the diet are readily transferred to the liver and then the egg yolk. Naber[6] classified nutrients in the egg by responsiveness to dietary change and determined that all the fat-soluble vitamins, including A and E, and the unsaturated fats, linoleic and linolenic acids, were egg responsive and that hen diet had a marked influence on the egg concentration. Egg yolk vitamin A levels were significantly increased, in a

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study from 0 to 32 weeks, at the first measure at 4 weeks, versus hens fed an unsupplemented control diet[7]. Egg yolk vitamin B_{12} levels measured weekly following dietary supplementation showed significant increases in yolk concentration within 1 week[8].

Studies of pastured poultry, however, are limited. In the UK Tolan et al.[9] compared the chemical composition of eggs produced by hens at six different research and educational institutions, in either: (1) cages, (2) floor pens, or (3) with access to grass, supplemented with a grain ration. Although the researchers did not compare the omega-3 fatty acid concentration of the eggs, the hens given access to grass tended to have more retinol than the eggs of the other hens, although differences were not significant at the $P < 0.01$ level used to test for significance.

In Spain, Lopez-Bote et al.[10] compared the diet and eggs of hens fed a commercial mixed feed for laying hens in Spain, to the eggs of 'free-range' hens. The free-range hens were given access to natural grassland, dominated by Italian ryegrass (*Lolium perenne* L.), and were fed 50 g hen^{-1} day^{-1} of the commercial hen feed. The grass compared to the commercial feed mix had 13-fold more α-tocopherol (vitamin E), 20-fold more linolenic acid (an omega-3 fatty acid) and 2.66-fold less linoleic acid (an omega-6 fatty acid). After 28 days on the two different dietary treatments (e.g. grass+commercial feed versus commercial feed), the egg yolks of the free-range hens had 30% more α-tocopherol ($P < 0.01$) and almost three-fold more ($P < 0.001$) omega-3 fatty acid than the eggs of the commercially fed hens. The ratio of omega-6 to omega-3 was also significantly lower ($P < 0.001$) in the pastured hens compared to those fed only commercial feed[10].

Research has shown that plants have the highest concentrations of unsaturated fats when they have a high leaf to stem ratio compared to stages of development when plants have a high proportion of stem tissue[3]. We have also found that vegetative legumes had more linolenic acid than grass species[11]. Since hen eggs are highly responsive to dietary changes of vitamins A and E, and the unsaturated fats, linoleic and linolenic acids[6], and because pastured hens can be rotated to species-specific pastures, we evaluated whether moving pastured hens to forage grass or common legume (alfalfa, red and white clover) pastures would influence hen egg composition. And because pastured poultry may have nutritional benefits that could enhance market value, we wanted to compare the eggs of pastured and caged birds to assess whether legume or grass pastures influenced egg composition.

Materials and Methods

Pastures

The experiment was conducted at the Pennsylvania State University Dairy Cattle Research and Education Center in State College, Pennsylvania (40°50′N, 77°51′W, elevation 352 m) from 1 July through 11 August 2002. The predominant soil series was a Hagerstown silty clay loam (fine, mixed, mesic Typic Hapludalfs, 3–8% slope). Prior to the experiment, the field was rotationally grazed with dairy heifers and dry cows, with excess forage harvested for haylage. Pastures were mowed occasionally to maintain them in similar vegetative stages of development. Lime, phosphorus and potassium were applied to the experimental area according to soil test recommendations to achieve optimum levels for forage production.

Three pastures were evaluated in this experiment: (1) alfalfa: 'Alfagraze' alfalfa with minor contributions of 'Pennlate' orchardgrass (*Dactylis glomerata* L.), 'Bull' tall fescue (*Festuca arundinacea* Schreb) and 'Saratoga' smooth bromegrass (*Bromus inermis* Leyss.); (2) red and white clover: 'Cinnamon' red clover and 'California Ladino' white clover with minor contributions of 'Pennlate' orchardgrass, 'Bull' tall fescue and 'Saratoga' smooth bromegrass; and (3) mixed cool-season grass pasture dominated by naturalized ecotypes of cool-season grasses that had been planted about 30 years prior to the experiment. The dominant species were orchardgrass, and smooth bromegrass, with some quackgrass, Kentucky bluegrass (*Poa pretense* L.), timothy (*Phleum pratense* L.) and tall fescue.

Experimental design

We compared the effect of moving foraging hens among three different pasture types on the hens' eggs, using a cross-over design[12]. Three groups of 25 pastured hens foraged on one of three pasture treatments for 14 days. The hens were then rotated to the other two pasture treatments, each for 14 days. The eggs of the three groups of chickens were collected for comparison on the last 3 days of each 14-day treatment period (days 12, 13 and 14). To compare the eggs of pastured hens to caged hens fed a commercial hen mash, we used a two-way design. Another group of 50 sister hens in cages was maintained under commercial conditions over the same 6-week experimental period. Caged hens' eggs were collected to compare to the pastured hens' eggs at the end of the first and last (the third) feeding periods. We compared the three pasture feeding treatments and the caged feeding treatments with a pre-planned contrast (pastured versus caged hens).

Animal management

Four weeks prior to putting the birds on pasture, the 75 pasture treatment pullets were offered supplemental alfalfa hay *ad libitum* (12 weeks) in floor pens indoors. Hy-Line variety brown egg laying pullets (age 12 weeks) were stratified by weight; 50 birds were assigned to commercial cages (387 cm^2 bird^{-1}) in an environmentally controlled room at 23°C. Caged birds were fed commercial hen mash [see Table 1, 16.9% crude protein (CP), 2863 kcal kg^{-1} metabolizable energy (ME)] and water *ad libitum* for the duration of the trial, to reflect management practices of a commercial confinement operation.

Table 1. Commercial hen mash composition.

	($kg\,T^{-1}$)
Bakery by-product meal	20
Canola meal	50
Corn	551.64
Distillers dried grain solubles	60
Dicalcium phosphate	1.50
Calcium chips ($CaCO_3$)	53.5
Poultry meal	80
Salt	2.5
Soybean meal	98.5
Limestone	39.5
Wheat middlings	29
Fat (animal and vegetable blend)	6
Methionine (liquid)	4
Lysine	1.65
Threonine	0.3
Enzymes (Avizyme® 0.75, phytase 0.06)	0.4
Vitamin premix	0.5
Trace mineral premix	0.5
Choline chloride	0.5

Three weeks prior to the beginning of the experimental trial (16 weeks), the pasture treatment pullets were acclimated to a pasture adjacent to the experimental area. On day 0 of the experiment (1 July), the pasture feed treatment hens were randomly assigned and given access to one of three pasture mixtures. Each group of 25 birds was then rotated to a different forage treatment every 14 days until all three hen groups had grazed all three forage treatments (42 days total, 11 August). Pastured hens received $70\,g\,hen^{-1}\,day^{-1}$ of commercial hen mash ($35\,g\,hen^{-1}$ at 12.00 and at 20.00 hours), and calcium carbonate chips and water *ad libitum*. The birds were given access to the pasture treatment that they were assigned to from 08.00 to 20.00 hours daily. At 20.00 hours, pastured hens were confined to mobile coops (2.44×3.05 m) for the night for protection from predators and to encourage egg-laying in coop nests.

The hen coops were on wheels, and hens were moved to a new paddock every 3 days to maintain fresh forage for the hens. Each coop contained three colony nests, a 45.7 cm diameter pan feeder, and a nipple drinker system sufficient for 25 birds. An electrified polywire poultry fence (14 horizontal wires, 1.2 m height, 889 mm semi-rigid stay spacing, 49.8 m linear perimeter; Kencove Farm Fence Supplies, Blairsville, Pennsylvania, USA) was used to create temporary paddocks of 6.9×10^{-3} ha area to restrict them to their assigned pasture treatment and for predator protection for the birds during daylight hours.

Forage sampling methods

Plant tissue for fatty acid analysis. On day 6 of each 2-week treatment period, immediately prior to hens foraging, a 'hand-plucked' sample that mimicked the foraging action of the birds, was collected from four random locations in each pasture treatment. Approximately 20 g dry matter (DM) was collected for fatty acid analysis. Plant tissue samples were immediately frozen in liquid N, freeze-dried, returned to the laboratory, ground to pass a 1 mm screen, and stored in a −80°C freezer until they were analyzed for fatty acid composition. The one-step hexane solvent and methylation procedure[13] was used to process the samples for subsequent analysis by gas chromatography.

Botanical composition, leaf to total DM analysis and forage mass. To estimate botanical composition, leaf to total DM and forage mass available to the hens, on days 2, 6 and 10 of each treatment period, two parallel quadrats (40×9 cm) of forage were harvested from four random locations in each paddock. Samples were divided into three subsamples. One subsample was divided into the primary live photosynthetic tissue (leaves) and all other plant tissues. Both of the live plant tissue fractions were dried separately in an oven at 65°C to a constant dry weight and weighed. Leaf-to-total DM ratio was determined by dividing the weight of leaf DM by the weight of the total above-ground plant DM (leaf tissue + other plant tissues).

A second subsample was divided into botanical components: alfalfa, red clover, white clover, grass species, other broadleaf species and dead material. The separated materials were dried at 65°C in a forced-air oven and weighed, and used to estimate botanical composition. The remaining sample was divided into live and dead material, dried at 65°C in a forced-air oven and weighed. To estimate forage mass, the live dry weight of the three subsamples was added together [(1) leaf and other plant tissue separates; (2) botanical separates; and (3) the remaining live material] and divided by the total area sampled.

Hens and egg

Hens were weighed at the beginning and end of each 2-week period. Eggs were gathered from each treatment group daily and recorded. Hen-day egg production was calculated as: (total eggs per 14-day period/hen number × 14 days) × 100. On the last 3 days of each 2-week treatment period (days 12, 13 and 14), 11 eggs from each of the four treatment groups were chosen at random from the approximately 18–25 eggs. Each egg was weighed; yolk, egg white and shell were separated and weighed.

Since the egg fat-soluble vitamins and other lipids are entirely in the yolk, all measures of egg nutrients herein are derived from yolk analysis. Three eggs were randomly selected from the 11 eggs collected from each treatment group on each of the last 3 days of each experimental period, and the egg yolks were pooled. A total of three pooled-yolk samples per treatment (9 yolks total) were sent to the University of Missouri Experiment Station Chemical Laboratories (Columbia, Missouri, USA) for analysis of total fat, omega-3 fatty acid content and cholesterol. Egg

yolks of the caged hens were only analyzed from periods one and three. Fat was analyzed by acid hydrolysis according to the AOAC method 954.02[14]. To quantify the fatty acids, samples were prepared by saponification–extraction in ethanolic KOH, converted to methyl esters using the boron triflouride method, and were analyzed using gas chromatography, according to the AOAC method 996.06[15]. Cholesterol was also saponified using KOH and quantified according to the AOAC method 994.10[14]. Omega-3 and omega-6 yolk weight per egg were calculated for each of the last 3 days of the experiment by multiplying the percentage of omega-3 and omega-6 fat by the percentage of total fat per egg, multiplied by the mean egg yolk weight.

Egg vitamins A and E. Five eggs were randomly selected from the 11 eggs collected from each treatment group on each of the last 3 days of each experimental period, and the five egg yolks were pooled. Three pooled yolk samples (15 yolks total) from each treatment were sent to Warren Analytical Laboratory (Greeley, Colorado, USA) for analysis of vitamins A and E (α-tocopherol). To quantify vitamin E, samples were saponified with alcoholic KOH, extracted with an organic solvent, and separated using a high pressure liquid chromatography (HPLC) silica column and florescence detection using a modification of the methods of Cort et al.[15] and Speek et al.[16,17]. For vitamin A, a 5 g yolk sample was combined with denatured alcohol (40 ml), pyrogallol solution (10 ml) and KOH (10 ml). The mixture was heated on a mantle and allowed to reflux on a condenser apparatus for 45 min. After cooling, the mixture was transferred to a 100 ml volumetric flask and was made up to 100 ml total volume with alcohol. After mixing thoroughly, a 30 ml aliquot was transferred to a clean centrifuge tube and was centrifuged for 15 min at $1200 \times \boldsymbol{g}$. An aliquot (15 ml) of the supernatant liquid was transferred to a clean 50 ml centrifuge tube and was combined with hexane (15 ml) and deionized water (10 ml). After vigorous shaking, the sample was centrifuged again as above. Two 5 ml aliquots of the hexane (top) layer were transferred to new glass culture tubes (16×100 mm) for retinol analysis. Each sample was evaporated to dryness with an N-Evaporator, and chloroform (100 µl) was added to each dry tube with mixing; then 1 ml of methanol was added and mixed. Samples were filtered through 0.45 µm discs and collected in amber glass vials. HPLC was performed with a Waters 515 pump system, 717 Autosampler, Model 470 fluorescence detector and a Nova-Pak C-18 column. Analysis was conducted with a flow-rate of 1.0 ml min^{-1}, with a column temperature of 35°C, and peak detection at 310 nm excitation and 470 nm emission. The mobile phase was 90 : 10 methanol/water and the injection volume of the sample was 50 µl (Warren Analytical Laboratory). Amounts of vitamin A and E per egg were calculated for each of the last 3 days of the experiment by multiplying the concentration of vitamins A and E by the mean egg yolk weight.

Statistical analysis

Analysis of variance was conducted on the forage data collected from each new paddock (botanical composition, forage mass, leaf to total ratio and plant fatty acids) with treatment period, pasture treatment and the interaction of treatment period by treatment as fixed effects using the GLM procedure of SAS[18]. Tukey's test was used to compare means, and means were considered different when $P < 0.05$.

Analysis of variance was also conducted on the hen and egg data (hen weight, hen-day egg production, egg and yolk weight, and egg fat composition, vitamins A and E) using PROC GLM of SAS. The experimental unit for the egg and yolk weight was the average of the eggs randomly selected from the eggs laid by the 25 hens on the last 3 days of each experimental period (days 12, 13 and 14). For the egg vitamin and fat analyses, the experimental unit was the average of the five or three pooled eggs, respectively, collected on the last 3 days of each experimental period. Since we did not collect the eggs for the analyses from the same hens, we did not conduct repeated measures analyses.

We compared the pasture treatments alone with experimental period and feed treatment as fixed effects, and group of hens that rotated among the pastures as a random effect. Tukey's test was used to compare means of the variables and differences were considered significant when $P < 0.05$. To compare the three pastured feeding treatments to the caged feed treatment, we conducted analysis of variance with PROC GLM of SAS with period and feed treatment as fixed effects. We used a pre-planned contrast to compare the pasture treatments to the caged treatment; the contrast was considered significant when $P < 0.05$. The hen-day egg production percentage data was transformed (arc sine); however, the percentage hen-day egg production data are reported herein for ease of interpretation.

Results

The average maximum and minimum temperatures, total precipitation and the 30-year normal temperatures and precipitation during the three periods of the experiment (1 July–11 August 2002) are shown in Table 2. Temperatures in 2002 during the experiment were similar to the 30-year normal temperatures. Average maximum and minimum temperatures were slightly higher than the normal temperatures in the second and third periods (largest differences were 1.7°C. between maximum temperatures and 2.5°C between minimum temperatures). Rainfall during the experiment was limited, particularly in periods 1 and 3, in comparison to the 30-year normal. Rainfall averaged eightfold lower than the 30-year normal precipitation in periods 1 and 3, and was about half the 30-year normal in period 2.

Botanical composition

The DM contribution of legume and grass did not differ ($P < 0.05$) between the alfalfa and clover legume treatments

Table 2. Average maximum and minimum temperatures and total rainfall for each 2-week experimental period in 2002 and 30-year averages.

Period: dates 2002	Experimental period average		30-year average		Experimental rainfall (cm)	30-year mean rainfall (cm)
	T-max (°C)	T-min (°C)	T-max (°C)	T-min (°C)		
1: 7/1–7/14	28.7	16.5	27.8	16.1	0.5	4.2
2: 7/4–7/28	28.6	19.0	27.8	16.1	2.0	4.2
3: 7/28–8/11	30.3	17.7	27.7	15.9	0.4	3.8

Table 3. Botanical composition of legume, grass, other broadleaf species and dead plant tissue in the pasture treatments.

Treatment	Legume	Grass	Other broadleaves	Dead
	----------(g kg^{-1} DM)----------			
Alfalfa	730a	140b	30a	100b
Clover	700a	110b	30a	160b
Grass	0b	620a	20a	360a
P>F	0.0023	0.0063	NS	0.0001

a, b, c, designate treatments that differ significantly ($P < 0.05$) among treatments, comparisons are within columns only.
NS indicates values did not differ significantly among treatments.

(Table 3). However, the legume proportion decreased ($P = 0.002$) over the experiment, from 820 and 780 g kg^{-1} DM in periods one and two, respectively, to 530 g kg^{-1} DM in period three. In the mixed grass pastures, grasses accounted for 620 g kg^{-1} DM of the pasture DM (Table 3). Orchardgrass comprised 150 g kg^{-1} DM, smooth bromegrass 250 g kg^{-1} DM, Kentucky bluegrass 90 g kg^{-1} DM, quackgrass 80 g kg^{-1} DM, timothy 40 g kg^{-1} DM and tall fescue 10 g kg^{-1} DM of the pasture DM. Orchardgrass, smooth bromegrass and tall fescue were also the grass species present in the legume treatments. The DM contribution of the other broadleaf species did not differ ($P < 0.05$) among the three pasture mixtures; and contribution of DM from dead material was twofold higher ($P = 0.0001$) in the grass treatment than in the legume treatments (360 versus 110 and 160 g kg^{-1} DM; Table 3). For most of the experiment, the three treatments were in vegetative stages of development. The grass treatment was vegetative throughout the experiment; the alfalfa was mid-vegetative, without flowers or buds. Red and white clovers were also in the mid-vegetative stage in periods one and three, but in the second period many plants were in the early flowering stage.

Forage mass, leaf to total DM ratio and plant fatty acids

The interaction of treatment and period was significant for forage mass ($P = 0.02$, Fig. 1A). In the first period, the legume treatments averaged 3182 kg ha^{-1}, three times more forage mass than in the grass treatment. In the second period, the forage mass did not differ between the alfalfa and grass treatments, but the clover treatment had twice as much forage mass as the grass treatment. Forage mass did not differ among the two legume treatments in any period, or among all treatments in the last period.

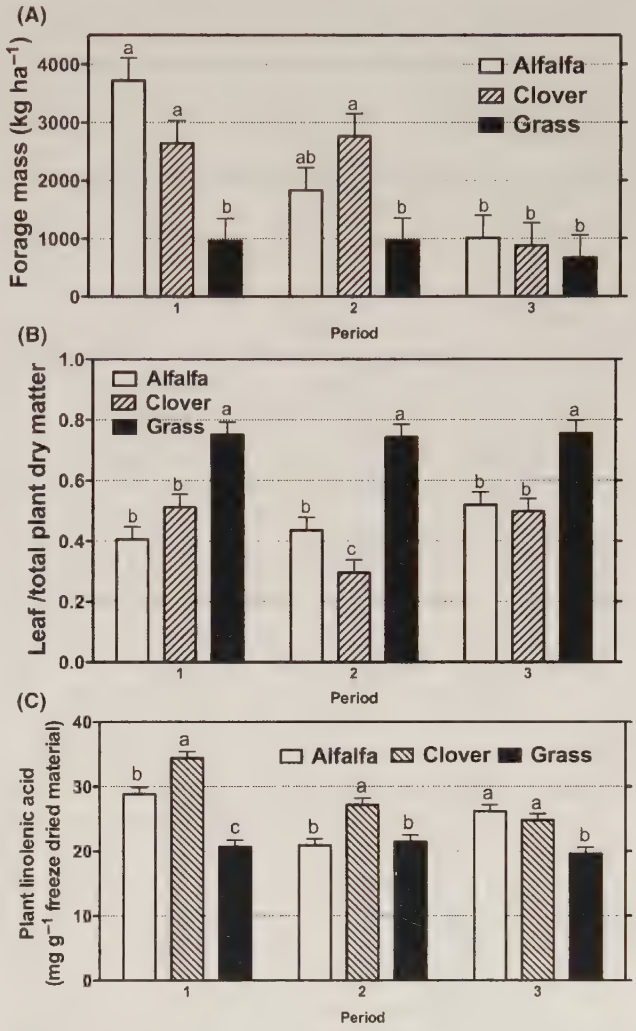

Figure 1. Forage characteristics of the three pasture plant treatments during the three 2-week experimental periods, with standard error bars. (A) Forage mass, (B) leaf to total above-ground DM ratio, and (C) forage linolenic acid concentration. a, b, c designate treatments that differ significantly ($P < 0.05$) within periods.

The interaction of treatment and period was also significant for the leaf to total DM ratio ($P < 0.05$,

Table 4. Mean egg and yolk weight, amount of omega-6 and omega-3 fatty acids, and cholesterol, vitamins A and E per egg yolk; and concentration of omega fatty acids cholesterol, vitamins A and E concentration per egg yolk in the three pasture treatments.

Pasture feed	Alfalfa	StdErr	Clover	StdErr	Grass	StdErr
			(g)			
Egg weight	54.71	0.806	54.48	0.806	52.34	0.806
Yolk weight	11.14	0.183	11.64	0.183	10.93	0.183
Omega-6 fats/egg yolk	0.55	0.019	0.60	0.019	0.56	0.019
Omega-3 fats/egg yolk	0.12	0.009	0.13	0.009	0.10	0.009
Cholesterol/egg yolk	16.5	0.54	17.8	0.54	16.9	0.54
			(IU)			
Vitamin A/egg yolk	330	27	340	27	300	27
Vitamin E/egg yolk	1.2ab	0.11	1.1b	0.11	1.3a	0.11
			(g per 100 g egg yolk)			
Linolenic (ωC18:3)	1.70	0.111	1.61	0.111	1.22	0.111
Stearidonic (ω18:4)	0.09	0.019	0.09	0.019	0.04	0.019
EPA (ω20:5)	0.04	0.003	0.04	0.003	0.04	0.003
C22:1	0.027a	0.0023	0.032a	0.0023	0.003b	0.0023
DPA (ωC22:5)	0.27	0.027	0.22	0.027	0.23	0.027
DHA (ω22:6)	1.69	0.102	1.63	0.102	1.50	0.102
Total omega-3 fats	3.76	0.213	3.58	0.213	3.03	0.213
Total omega-6 fats	16.64	0.147	16.98	0.147	16.90	0.147
Cholesterol	1.48	0.028	1.51	0.028	1.54	0.028
			(IU per 100 g egg yolk)			
Vitamin A	2900	187	2900	187	2700	187
Vitamin E	10.8ab	0.21	9.6b	0.21b	11.8a	0.20

Omega-3 fatty acids are bold. a, b, c designate treatments that differ significantly ($P < 0.05$) among pasture treatments.
DHA, docosahexaenoic acid; DPA, docosapentaenoic acid; EPA, eicosapentaenoic acid.

Fig. 1B). In the grass pastures, leaf to total DM ratio averaged 0.75 and was higher than the legumes in all periods. Leaf to total DM ratio for the legume treatments was similar in the first and third periods (averaging 0.45 and 0.50, respectively), but in the second period, the ratio dropped to 0.30 in the clover treatment, while remaining similar in the alfalfa treatment. This decrease probably occurred because the clover plants had begun flowering in second period, while the alfalfa treatments remained vegetative.

There was also a significant interaction of treatment and period for the concentration of linolenic acid (C18:3) in the plant tissues ($P = 0.0001$, Fig. 1C). In period one, clover had 20% more C18:3 than alfalfa and 70% more than the grass treatment. Linolenic acid concentrations were similar in alfalfa and grass in period two, and were 24% lower than in the clover treatment. In period three, the concentration of C18:3 decreased in the clover treatment to a level similar to the alfalfa pasture; but the legume treatments still had 30% more C18:3 than the grass treatment.

Hens

Livability at the end of the study was 100% for the pastured hens and 97.9% for the caged hens ($P < 0.0001$). Body weight of the pastured birds, while not significantly different at the beginning of the study (1540 g at 19 weeks), was influenced by the period of lay and treatments. At the end of the study the weight of the pastured hens did not differ significantly, but the caged hens weighed significantly ($P < 0.0001$) more than the pastured birds (1821 versus 1571 g) and closer to the 24-week of age breed-age standard[19]. Hen-day egg production did not differ among pasture treatments, but differed ($P = 0.0035$) between the caged hens and the pasture hen treatments, and over the three experimental periods ($P < 0.05$). Caged hens averaged 85% egg production over the three 2-week periods, and pastured birds averaged a significantly lower 72%. In both treatments, hen-day egg production was lowest in the first period (56%), and increased in the second (80%) and third periods (90%).

Egg mass and yolk fat composition

Egg weight, yolk weight, and the concentration of fat, cholesterol and total omega-6 fatty acids did not differ among the pasture treatments ($P < 0.05$, Table 4), nor among the pastured and caged treatments (data not shown), although they increased from the first period to the third period (Table 5). The concentration of the omega-3 fatty acids and the total amount of omega-3 did not differ, either among the pasture treatments (Table 4) or among the experimental periods (Table 5). Erucic acid (22:1) was the only fatty acid that differed in concentration among the eggs of hens that foraged on the pastured treatments, with lower concentrations in the eggs of the hens that foraged on grass (Table 4).

Table 5. Mean egg and yolk weight, amount of omega-6 and omega-3 fatty acids and cholesterol per egg yolk; and concentration of vitamins A, E and cholesterol in the egg yolks of all feeding treatments in the three experimental 2-week periods.

	1		2		3	
Period	**Mean**	**StdErr**	**Mean**	**StdErr**	**Mean**	**StdErr**
	(g per egg)					
Egg weight	50.89b	0.656	54.60a	0.803	56.15a	0.656
Yolk weight	10.37b	0.250	11.62ab	0.306	12.20a	0.250
Omega-6 fats	0.51b	0.023	0.58ab	0.028	0.64a	0.023
Omega-3 fats	0.10	0.005	0.09	0.006	0.11	0.005
Cholesterol	15.4b	0.32	17.2a	0.40	18.6a	0.32
	(IU per egg)					
Vitamin A	252b	21.0	300a	25.7	353a	21.0
Vitamin E	0.8b	0.07	1.0ab	0.09	1.0a	0.07
	(g per 100 g egg yolk)					
Cholesterol conc.	1.50	0.03	1.49	0.03	1.50	0.03
	(IU per 100 g egg yolk)					
Vitamin A conc.	2400	180	2600	220	2900	180
Vitamin E conc.	8	0.6	10	0.8	10	0.6

a, b, c designate treatments that differ significantly ($P < 0.05$) among periods.

Table 6. Fatty acid profile of the eggs yolks from hens on alfalfa, clover, and grass pastures and caged hens, averaged across the three pasture experimental periods.

	Pastured				**Pastured versus caged contrast significance**
	Alfalfa	**Clover**	**Grass**	**Caged**	
	($g\ kg^{-1}$ yolk)				
Total fat	298	304	300	305	NS
	(% of total yolk fatty acids)				
Mryistic (14:0)	0.33	0.32	0.33	0.31	NS
Myristoleic (14:1)	0.030	0.027	0.030	0.029	NS
Palmitic (16:0)	24.86	24.16	24.58	24.26	NS
Palmitoleic (16:1c)	3.50	3.37	3.38	3.11	NS
Stearic (18:0)	7.86	7.67	7.67	8.02	NS
Elaidic (18:1t)	0.52	0.51	0.48	0.63	0.039
Oleic (18:1c)	38.73	38.92	38.86	41.99	0.0015
Linoleic (C18:2)	14.54	15.02	14.84	14.21	0.0339
Linolenic (ω18:3)	1.67	1.61	1.22	0.33	0.0012
Stearidonic (ω18:4)	0.09	0.09	0.04	0.07	NS
Arachidic (20:0)	0.04	0.04	0.04	0.05	NS
Arachidonic (20:4)	1.97	1.96	2.06	2.10	NS
EPA (ω20:5)	0.04	0.04	0.04	0.02	0.0022
Docosanoic (22:0)	0.127	0.117	0.128	0.137	0.0035
Erucic (22:1)	0.03	0.03	0.00	0.00	NS
DPA (ω22:5)	0.27	0.22	0.23	0.10	0.005
DHA (ω22:6)	1.69	1.63	1.50	0.76	0.0014
Ligonceric (24:0)	0.04	0.03	0.04	0.04	NS
Total omega-3	3.76	3.59	3.03	1.28	0.0008
Total omega-6	16.50	16.98	16.90	16.31	NS
Omega-6/omega-3	4.44	4.76	5.70	12.05	< 0.0001

Omega-6 fatty acids are italicized and omega-3 fatty acids were bold.
NS indicates pre-planned contrasts that were not significant.
DHA, docosahexaenoic acid; DPA, docosapentaenoic acid; EPA, eicosapentaenoic acid.

The concentrations of the omega-3 fatty acids, however, were higher in the eggs of the pastured hens than the caged hens, with 4.5-fold more linolenic acid ($P = 0.0012$), twofold more eicosapentaenoic acid (EPA) ($P = 0.0022$) and docosahexaenoic acid (DHA) ($P = 0.0014$) and 2.4-fold more docosapentaenoic acid (DPA) ($P = 0.0050$) than the

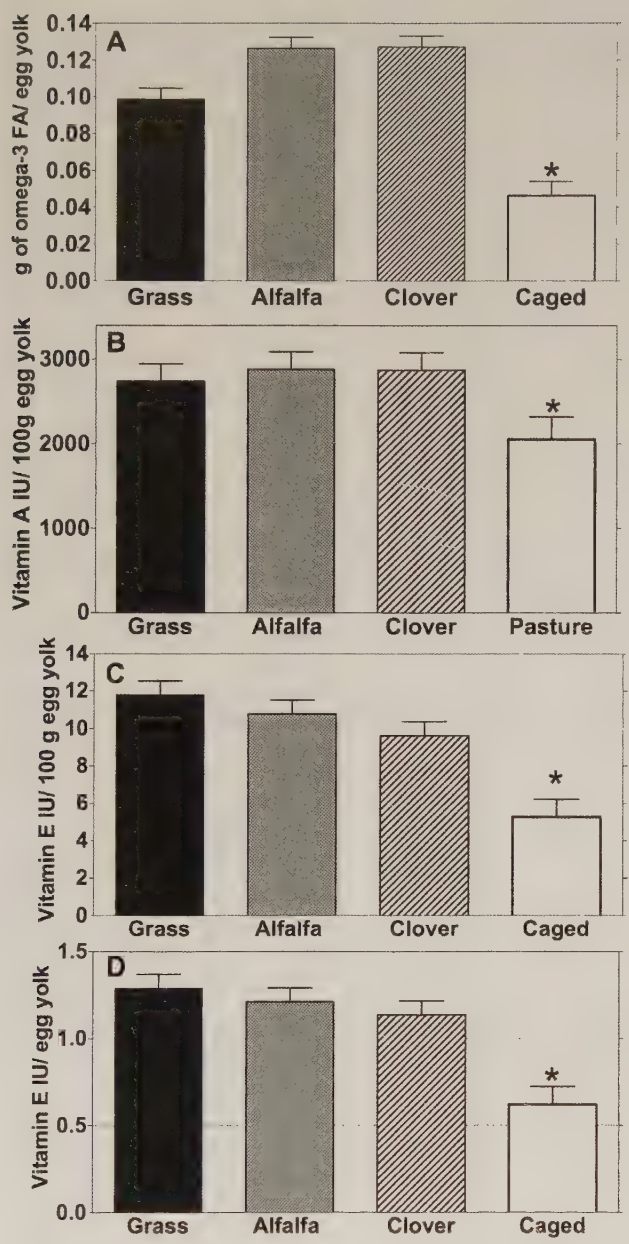

Figure 2. Egg yolk characteristics of the four feeding treatments averaged over the three 2-week experimental periods with standard error bars: (A) omega-3 fatty acid amount (mg) per egg yolk, (B) vitamin A concentration of the egg yolks, (C) vitamin E concentration in the egg yolks and (D) vitamin E amount of the egg yolks. *Indicates that the pre-planned contrast of the pastured treatments versus the caged treatments was significant ($P < 0.05$).

caged hens' eggs (Table 6). In total, the pastured hens' eggs had 2.7-fold higher concentration of omega-3 fatty acids ($P = 0.0008$) than the caged hens', and the ratio of omega-6 to omega-3 fatty acids was 2.4-fold lower ($P < 0.0001$) in the pastured eggs than in the caged hens' eggs. In addition, the total amount of omega-3 fat (g per egg yolk) of the pastured hens was 2.5-fold higher than that of the caged hens ($P = 0.0007$; Fig. 2A). In addition, compared to the eggs of the caged hens, the eggs of the pastured hens had a 4% higher ($P = 0.0339$, Table 6) concentration of the omega-6, linoleic acid (C18:2), and lower concentrations ($P < 0.05$, Table 6) of elaidic (18:1t), oleic (18:1c) and docosanoic (22:0) acids.

Egg yolk vitamins

Although egg yolk vitamin A concentration and total amount per egg did not differ among hens that foraged on the pasture treatments, the eggs of the hens that foraged on pasture averaged a 38% higher concentration of vitamin A (IU per 100 g egg yolk) than the eggs of caged hens (Fig. 2B). The total amount of vitamin A (IU per egg yolk), however, did not differ among feed treatments (data not shown) but was significantly higher in period 3 of the experiment than in first period ($P < 0.05$, Table 5).

When only the pasture treatments were compared, the concentration (IU per 100 g egg yolk) and total amount of vitamin E (IU per egg yolk) in the eggs of the hens that foraged on grass were 14 and 23% higher, respectively, than in the eggs of the hens that foraged on clover ($P < 0.05$, Table 4). Further, eggs of pastured hens had twice the concentration and total amount of vitamin E per egg of the caged hens (Fig. 2C and D, respectively). Vitamin E concentration (IU per 100 g egg yolk) did not differ among periods, but the amount of vitamin E per egg (IU per egg yolk) was significantly higher in the second and third periods of the experiment than in the first period (Table 5, $P < 0.05$).

Discussion

There was some variation in forage mass among the pasture treatments and experimental periods, with the grass treatment often producing a higher leaf to total plant ratio. None of these forage characteristics, however, had a pattern that explained the variation in plant linolenic acid concentrations (Fig. 1). Forage samples of the pasture treatments differed in linolenic acid concentration (C18:3), although eggs from hens foraging the pasture treatments did not differ in total linolenic acid or total omega-3 fatty acid composition. This suggests that the hens selectively foraged to obtain similar fatty acid diets from all of the pasture treatments, or that the experimental forage and plant linolenic acid concentration differences were not large enough to influence hen egg omega-3 fatty acid composition.

The only differences observed among eggs of hens that foraged the pasture treatments were in erucic acid (22:1) and vitamin E (Table 4). Eggs of hens that foraged on grass produced eggs with less erucic acid and a 14% higher concentration of vitamin E and 23% more vitamin E in total per egg, suggesting that grasses may provide hens with more vitamin E than clover. Richardson et al.[20] also found that grass silage enhanced beef vitamin E concentration compared to red clover silage, or a red clover and grass silage mix (50:50 mix) when fed to beef cattle. The meat of the cattle fed grass silage had significantly more vitamin E

than the cattle fed red clover or the red clover and grass silage mixture.

The eggs of the caged hens and the pastured hens did not differ in weight, total fat, cholesterol and omega-6 fatty acids. The eggs of the pastured hens, however, had significantly higher concentrations of vitamins A and E and omega-3 fatty acids. Vitamin A concentrations were almost 40% higher in the pastured hens than the caged hens' eggs, but the total amount of vitamin A per egg did not differ between the pastured and caged hens. Although egg and yolk weights did not differ statistically among the treatment hens, the lack of difference in vitamin A per egg suggests that egg weight variation among feed treatments and the observed increase in egg weight over the experimental periods countered the vitamin A concentration differences. On the other hand, the small sample size may also have limited the power of the statistical tests.

The pastured hens' eggs also had almost twice as much total vitamin E (IU per egg yolk) and total omega-3 fatty acids per egg; and the ratio of omega-6 to omega-3 fatty acid was less than half the ratio of the caged hens' eggs. Concentrations of vitamin E (IU per 100 g egg yolk) and long-chain omega-3 fatty acids (EPA, DPA and DHA) were twice as high in the pastured hens' eggs, and the total omega-3 fatty acid concentrations were 2.7-fold higher than in the caged hens' eggs. These results are similar to the findings of Tolan et al.[9], in the UK, and particularly to those of Lopez-Bote et al.[10], in Spain, who found that hens given access to grassland produced eggs that had almost three fold more omega-3 fat and 30% more vitamin E than the eggs of caged hens. Further, the omega-3 fatty acid and vitamin E egg concentrations that Lopez-Bote et al.[10] measured in Spain, were in a range similar to the values measured herein. The omega-6 to omega-3 fatty acid ratio in the caged and free-range hens (5.21 versus 18.73, free-range versus caged[7]) was also similar to the ratios in this study (5.0 versus 12.05, pastured versus caged).

The caged hens consumed an average of 113 g mash $hen^{-1}\,day^{-1}$, typical for Hy-Line brown egg hens at this age[19]. With the daily allotment of 70 g mash $hen^{-1}\,day^{-1}$ (11.8 g CP, and 200 kcal ME) to pastured hens, hen-day egg production was 15% lower than the caged hens and their body weight at the end of the experiment was 14% lower than the caged hens. Hens did not forage to the degree necessary to meet their requirements for energy and protein when compared to the caged birds. Although egg production and body weight were greater than that expected of birds maintained on only 70 g mash $hen^{-1}\,day^{-1}$, they only derived approximately 13.2% of their energy requirement (36 kcal ME) and 21.5% of their CP needs (3.9 g) from pasture foraging. The pastured hens were still lacking dietary protein and energy (approximately 2.3 g CP and 35 kcal ME) on a daily basis to match the intake of the caged hens. Buchanan et al.[21] found that Leghorn roosters only obtain small amounts of energy from pasture forage (285–463 kcal kg^{-1} forage, as is basis). And previous work with broiler chickens has shown they are unable to overcome a 7% reduction in dietary energy with supplemental forage[22]. We have since estimated that, at the level of voluntary forage consumption of hens in this study, pastured hens would require more than 13 g additional mash feed to sustain body weight and egg production equal to that of the caged hens. Although 83 g $hen^{-1}\,day^{-1}$ (70 g + 13 g) would most likely provide the CP needs for the pastured birds to maintain similar egg production and body weight to the caged birds, additional mash would be required to provide needed energy to support the greater activity of pastured hens. Supplementing the birds with additional mash, however, would likely result in reduced omega-3 fatty acid and vitamin A and E concentrations in their eggs. Supplementing with chia (*Salvia hispanica* L.), flaxseed (*Linum usitatissimum* L.)[23], fish meal, or another feed ingredient high in omega-3 fatty acids would be another means to increase the total omega-3 fat concentration and decrease the omega-3 to omega-6 ratio in the hens' diet and eggs. Further research is needed to identify how to optimize pastured poultry feed supplementation for optimum egg production, hen welfare and egg nutritional quality.

In summary, although the pasture mixtures differed in linolenic acid concentration, the eggs from hens moved among the pasture treatments did not differ in linolenic acid or total omega-3 fatty acid concentration. In comparison to eggs of caged birds, the pastured hens' eggs had twice as much vitamin E and long-chain omega-3 fatty acids, and 2.5-fold more total omega-3 fatty acids. Pastured hens, however, also weighed less and produced fewer eggs than caged hens, indicating that they should be supplemented with more dietary energy and crude protein, which could reduce the observed egg omega-3 fat and vitamins A and E concentrations.

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Is conventional agricultural research fit for the purpose of supporting ecological agriculture? A case study of an attempted transition in Sweden

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Abstract

In order to increase ecological horticulture in Sweden, it is necessary to increase productivity while reducing working hours. To improve the relevance of research results as a base for such transitions, a Participatory Learning and Action Research (PLAR) group was added to a conventional research project that aimed to find options for using green manure as a multifunctional tool in vegetable production. The project consisted of four work packages looking at different aspects of a system of interest defined by researchers. The PLAR group sought to evaluate the agronomic outcome of the conventional research outputs but came to add qualitative experience of using the different manuring methods tried. The article reports on the evaluation of the PLAR activities as well as on issues of cooperation and understanding The difficulties and constrains that arose revealed the limitations of conventional research as a means for supporting ecological horticulture transitions, but using PLAR as an 'add on method' is also shown to be inadequate for helping producers effect the transitions required. Discussion on the robustness of the data generated and the stability of the approach show the importance of using approaches that are fit for practice when extending research to develop ecological horticulture to include participation with practitioners. Moving from conventional research approaches to trans-disciplinary approaches is not easy and includes the need to relate the contextual knowledge of farmers to the abstract knowledge of scientists.

Key words: ecological horticulture, Participatory Learning and Action Research, research transition, green manure, Sweden

Introduction

In Sweden, a political decision has been taken to increase the acreage of certified organic agricultural production from 6%, in 2006, to 20% of the total production area by the year 2010[1]. The consumption of certified organic food within the public sector (state institutions covering healthcare, law, education, defence, etc.) should reach 25% of the expenditure for the food consumed[2]. These goals have been decided as a means of fulfilling national environmental objectives such as a nontoxic environment, a varied agricultural landscape, good quality ground water and a rich diversity of plant and animal life. Within the horticulture sector, organically grown vegetable production accounted for 9.4% of the total horticultural field production in 2005[3]. It is seen as a challenge to increase production to the levels set in the above goals. Competition from imported vegetables is severe, keeping domestic prices to growers low, and there is a need for both increased profitability and cropping reliability to secure expansion in the area[4]. Problems such as weeds, long working hours, lack of capital for investments and complex management situations are considerable but there are also problems of pathogens and nutrient management[5,6].

In 2005, in Sweden, there were 470 certified organic horticultural field producers, with an average acreage of 1 hectare[7]. The main crops grown are onions, beetroots, carrots and cabbage—the last two often being financially the most important for growers. Supplies of Swedish produce have been limited during the past few years[4]. Organic vegetable production that is able to meet growers' expectations and national policy goals requires skilled growers who can plan and vary their crop rotations and are good soil managers. It is demanding and strenuous work

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and there is a need for solutions that will both improve production levels and reduce working hours.

In order for research to contribute to transitions improving ecological agriculture (agriculture striving for improved sustainability and accordance with the ecosystem principles, going beyond statues set for organic agriculture) there was an experienced need to improve the relevance to practical farming of research results. In 2002, a research project to study green manure as a multifunctional 'tool' within Swedish organic vegetable production was started at the Swedish University of Agricultural Sciences (SLU) to support the strive toward more 'ecological' agriculture. Green manure is frequently used for augmenting on-farm nutrient supply in Swedish agriculture. On farms without animals it is used by almost all organic producers today and on farms with animals the same effect is given through ley production (i.e., production of a mix of grass and leguminous plants), for grazing, hay and ensilage. A work package (WP) was added to the project to allow farmers, researchers, an extensionist and a facilitator to evaluate the output of the conventional research trials through Participatory Learning and Action Research (PLAR). The experience of implementing this WP, as an add-on within a conventionally designed research study, raises the questions addressed in this paper: is researching in the conventional way fit for the purpose of supporting ecological horticulture? Is a PLAR 'add-on' sufficient to overcome any shortfalls in the conventional approach?

The Research Study

The research project 'Green manure as a multifunctional tool in vegetable production' was implemented from 2002 through 2005. The study sites were spread throughout the country (Fig. 1), and also included one location in Denmark.

The overall aim was to gain a holistic understanding of what green manure, as a multifunctional tool for integrated vegetable production management, could add to locally adapted vegetable production systems. The investigation of different systems of green manure focused especially on its contribution in terms of nutrients, protection against pests and product quality. Four green manuring systems were included: ploughing-in of a growing ley crop, intercropping, digested sludge and composting.

The research was divided into three work packages (WPs 1–3). Each was based on disciplinary trials at three different research stations. In addition, it was planned that WP 1 (on nutrients) would be connected to a series of on-farm trials. The linkage would be implemented by constituting a collegial level[8] PLAR group (WP 4).

The study was directed by a steering committee, consisting of the study coordinator (SC), a senior responsible researcher for WPs 1–3, respectively, and the advisor responsible for WP 4. WPs 1–3 consisted in each case of senior researchers (R1:X–R3:Z) and a PhD student (PhD1–PhD3). The participatory WP (WP 4) team was made up of an organic farming advisor, a researcher on

Figure 1. Location of study farms and research stations.

plant nutrients (R4:1) and one on composting (R4:2) (both were also part of the plant nutrient WP), and the farmers (6 men/1 woman) from the six participating farms (F1–6), and a facilitator.

The design of the overall research study was informed by a system awareness, illustrated by the picture (Fig. 2) used by the study coordinator to explain the planning of the study at the first meeting (Sunnersta Herrgård, 4–5 March 2002). The imagined correlation between the productions systems and the relevance of the WPs are illustrated. At the time, despite the system awareness, it was not thought necessary to change the organization of the research as a conventional disciplinary research project. The underlying presumption was that knowledge would be produced through objective study of defined variables with reduced statistical variance and maximum expression of the treatment variables[9]. In the course of implementation, the disciplinary studies continued to be based on a series of objective trials and laboratory experiments of particular parts of the system of interest, separated in time and space. The research plan required that, following the completion of the project, the project steering committee would combine the outputs of the separate WPs into a total system analysis. The analysis was planned to allow a qualitative and quantitative evaluation through use of multivariate methods.

During the initial planning of the study, the PLAR WP was conceived as a discrete activity that would focus on the agronomic and economic evaluation of the green manure options studied by the other WPs, as illustrated in Figure 2.

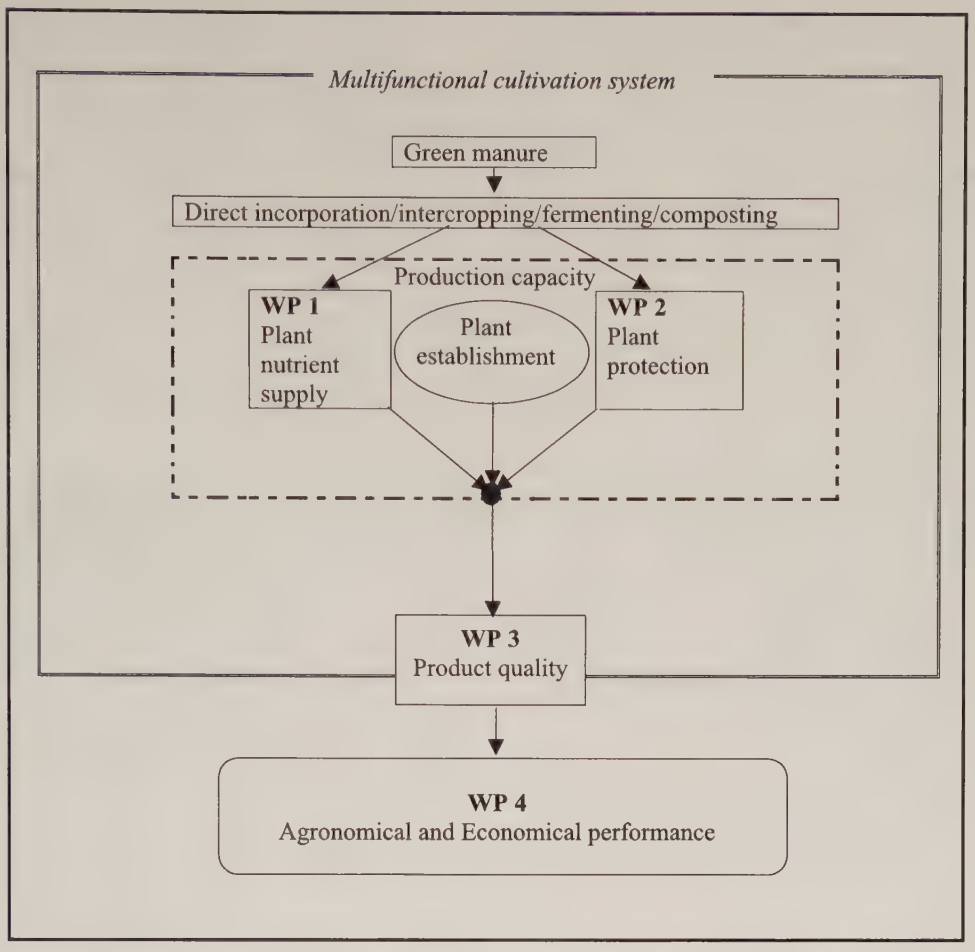

Figure 2. Systems picture modified from the application, used to explain the study at the first meeting of the overall study (Sunnersta Herrgård, 4–5 March 2002).

Sufficient inter-linkage between the WPs to support a systems approach was to be achieved through periodic steering committee meetings, twice a year, reports from each WP every 6 months, and by organizing two large seminars for all members of the study. The purpose of the seminars was to provide opportunities for the members of the WPs to present their work to each other. Two field trips to selected farmers, and to the research stations where the trials were conducted, also took place.

The group work

The participating farms were selected based on the farmers' degree of knowledge of organic farming, using length of time in organic farming as an indirect indicator (number of years in organic ranging between 7 and 27 at project start), cabbage production and geographic location. The advisor presented the study to the farmers from six farms that meet these criteria. Financial compensation was offered to cover the farmers' costs associated with meetings and trial work. When invited to participate, all accepted. The advisor became responsible for reporting to and liaising with the steering committee; the facilitator for guiding the process in the PLAR group; and the two researchers for guiding the on-farm trials.

Because of the large distances between the farms – approx 800 km from north to south – the WP 4 participants met mostly in an available conference room in Stockholm.

The first seminar for all study members (4–5 March 2002) was planned by the steering committee as an occasion for each WP team to present their plan of work. At this occasion the participatory group for WP 4 met together for the first time. The facilitator gave a short introduction to PLAR and PLAR tools, briefly explaining the approach for trans-disciplinary and systemic research and learning for enabling transitions that yield situational improvements. Then the advisor invited discussion of the on-farm trials that were designed to complement the on-station trials. At this point, the farmers added mulching to the manuring strategies to be studied. This suggestion was adopted and implemented in WPs 1–3. It was accepted that conventional *quantitative* designs would be used for the planned on-farm trials of the manuring options, in order for farmers to carry out their own *qualitative* evaluation of these trials, and for the results derived from the on-farm studies to be related to the on-station nutrient trials.

Table 1. Trials chosen by the participating farmers compiled.

Trials	Farmers					
	1	2	3	4	5	6
Direct ploughing in of ley before crop						
+No extra treatment	x	x	x	x		x
+Pelleted poultry manure	x	x		x		
+Compost						
Harvested ley and straw		x				
Harvested ley and horse manure rich on straw		x				
Whole crop cereal		x				
+Mulching		x		x		
+Intercropping						
Phacelia tanacetifolia Benth (Fiddleneck)				x		
Trifolium pratense (Red clover)				x		
Direct ploughing in of remnants after *harvested* ley before crop						
+No extra treatment			x	x	x	
+Pelleted poultry manure			x	x		
+Compost	x		x		x	
Harvested ley	x					
+Ensilage (as mulching and ploughed in)						
+Mulching				x		x
+Digested sludge			x	x	x	x
+Digested sludge and pelleted poultry manure					x	
+Fresh poultry manure						x
+Fresh poultry and pelleted poultry manure						x
+Cow manure	x				x	
+Cow manure and pelleted poultry manure					x	

Source: Group documentation 2002–2004.

At the second PLAR meeting, a group contract was negotiated, using key words to indicate how the group wanted their collaboration to be characterized. The facilitator also took the group members through a series of exercises designed to build the group dynamics and to illustrate differences in the learning and thinking styles of the participants. Each participant presented the individual goals that they hoped would be secured by the group.

The third meeting took place at one of the farms. The participants created together a large matrix table, mapping what the participants had interest in knowing more about within the overall study theme, if the group could deal with it and how, and what to do if the item mentioned was not within the capability of the group or the study. Some questions were noted for forwarding on to researchers in other WPs.

During the first three PLAR meetings, time and effort were given to adjusting the design of the research trials to the local conditions on the farms and to the farmers' resources, and for the farmers' questions to be answered; these questions continued to be discussed throughout the trial period. The final suite of on-farm trials from which farmers could choose were as follows: manuring with different kinds of compost, digested sludge, mulching and inter-cropping, complete ploughing-in of ley pasture or ploughing-in of the remnants after harvested ley pasture. Each farmer chose a different combination of trials (Table 1).

All the group meetings experienced time pressure and especially in the first three meetings, the focus was kept firmly on questions related to the design, establishment and management of the trials. Attendance in this crucial phase was high (Table 2). A small number of the researchers from WPs 1–3, visited members of WP 4 at a later stage, to present their ideas and discuss experiences.

During 2002–2004 (three growing seasons) the farmers implemented their chosen manuring trials, with adjustments and changes between seasons. In the trial fields, the soils were mapped; and for the ley, tests of dry matter content, measurements of ash and total carbon, nitrogen and potassium were taken. The measurements were to be used in the development of nutrient budgets. The farmers took diary notes on their research activities and photos were taken 'for the record' at the time of spreading the mulching and compost material.

The final meeting (Sunnersta Herrgård, 17 February 2005), was planned by the steering committee as the synthesis and conclusion of the whole study. Each WP team presented their results to the others. The farmers presented their own results and their experiences of working with the different 'sub-systems' in the on-farm trials. The day after, the participatory group held its own evaluation. The evaluation process was planned by the facilitator according to the interest expressed by the members of the group. The topics included outputs and outcomes, as well as the

Table 2. Attendance at the PLAR meetings.

PLAR-meetings	Participant:	WP 4 Researchers	Advisor	Facilitator	Farmers	Visitors
4 March 2004		1, 2	1	1	1, 2, 3, –, 5, 6	–
12 April 2002		1, 2	1	1	1, 2, 3, 4, 5, 6	Practitioner
4 July 2002		1, 2	1	1	1, 2, 3, 4, –, 6	–
22 November 2002		1, 2	1	1	1, 2, 3, 4, 5, –	–
31 March 2003		1, 2	1	1	1, 2, 3, 4, 5, –	R2:2
8 December 2003		1, 2	1	–	1, 2, 3, 4, 5, 6	SC, R3:1
6 April 2004		1, –	1	–	1, –, 3, 4, –, 6	SC, PhD2 R1:1, R2:1
18 February 2005 Evaluation		1, 2	1	1	1, 2, 3, 4, –, –	SC

Source: Group documentation 2002–2005.

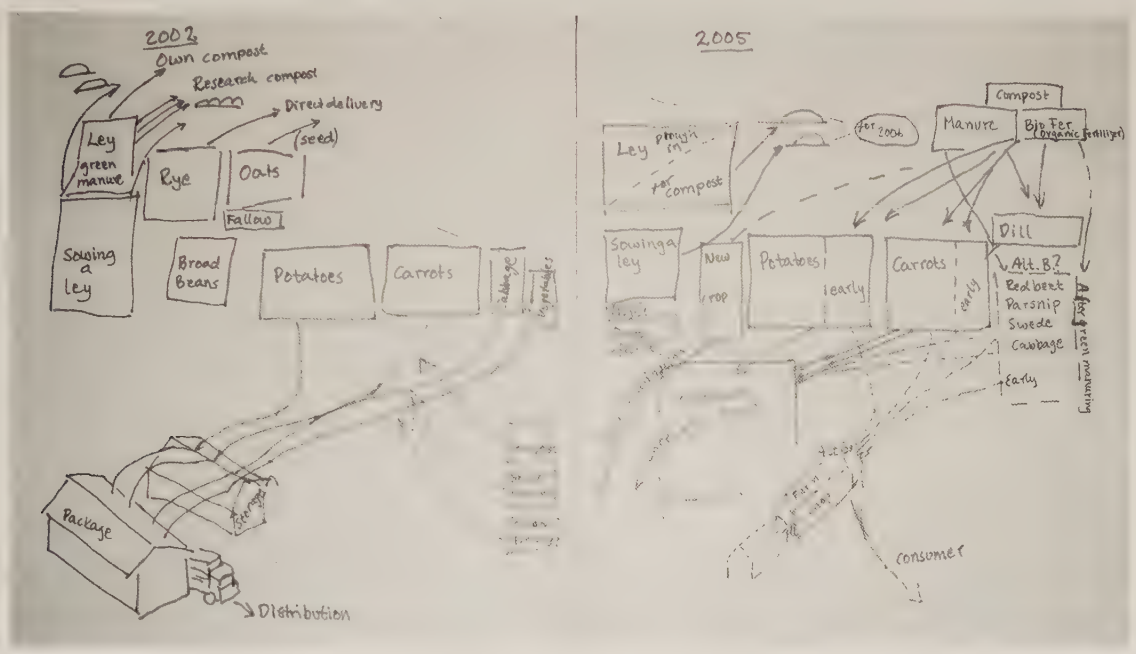

Figure 3. (a, b) Example of a flow diagram drawn by evaluation participant to discuss changes within the farm systems resulting from the participatory group work and the research program (F2, Sunnersta Herrgård 18 February 2005) (Copied and translated by the author).

process—the different activities and ways of working. Four farmers, the researchers, the advisor, the facilitator and the program coordinator took part.

Methodology

Primary data were recorded through participant observation, written notes taken at group work meetings, study seminars, the group evaluation day, the facilitators' diary, records taken during farm and study visits. Secondary information was drawn from projects proposal and reports. All researchers responsible for work packages and a farmer not present at the group evaluation day were interviewed individually. The information has been processed manually and written up as a case study[10].

Results

This section is divided into two parts. The first reports the findings from a participatory evaluation of the PLAR activities. It focuses on the practical issues that arose as a result of trying to implement conventional trials on-farm in a participatory process. The second focuses on issues of cooperation and understanding.

Evaluating the group work

The PLAR group engaged in several different activities, principally: eight group meetings including an evaluation day, two conference telephone meetings, two research study seminars (start and end), field trips, practical discussions, individual work, introductions to and reviews of the tools and exercises used, on-farm study visits by researchers and the advisor and visits to the PLAR group meetings by one or more of the researchers from the other work packages. The evaluation was carried out using participatory tools. Figures 3a and b show two diagrams comparing a farm system before the study and after. Figure 4 shows a timeline of when the decisions important for the

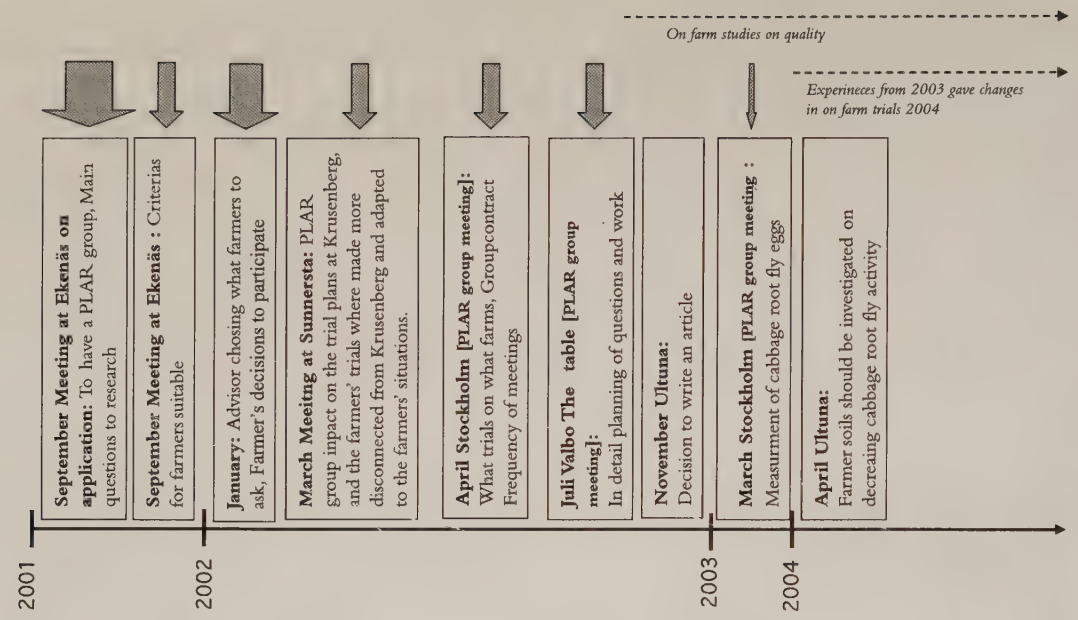
On farm studies on quality
Experinecces from 2003 gave changes in on farm trials 2004
September Meeting at Ekenäs on application: To have a PLAR group, Main questions to research
September Meeting at Ekenäs : Criterias for farmers suitable
January: Advisor chosing what farmers to ask, Farmer's decisions to participate
March Meeitng at Sunnersta: PLAR group inpact on the trial plans at Krusenberg, and the farmers' trials where made more disconnected from Krusenberg and adapted to the farmers' situations.
April Stockholm [PLAR group meeting]: What trials on what farms, Groupcontract Frequency of meetings
Juli Valbo The table [PLAR group meeting]: In detail planning of questions and work
November Ultuna: Decision to write an article
March Stockholm [PLAR group meeting : Measurment of cabbage root fly eggs
April Ultuna: Farmer soils should be investigated on decreaing cabbage root fly activity
2001
2002
2003
2004

Figure 4. Illustration of decisions affecting the process, and their weighted importance illustrated through the added arrows (SC, R4:1, R4:2, A1, Sunnersta Herrgård 18 February 2005. Translated and modified for publication).

Table 3. Base for discussing how the group thought their goals had been met. Scores were given by some with respect to the whole study and by some with respect to the work of WP 4 (modified for publication).

	☺	😐	☹
Get rid of Binadan and such	x	xxx	xxx
Social exchange	xxxxxxx	0	0
Learn from experienced growers	xxxxx	xx	0
Learn more on mulching	xxxx	xxx	0
Learn more on green manure	xxxx	xxx	0
Be able to have green manure as base crop	xxxxxxx	x	0
Develop cabbage production with economy	0	xxxxxxx	0
Get results for ordinary businesses	xx	xxxxxxx	x
Develop the system	xxxx	xxx	0
Learn about PLAR	xxxx	xxx	0
Extended knowledge on PLAR	xx	xxx	x
Learn from research	xxxxxxx	0	0
Find possible manure for late varieties	x	?	xxxxx

Source: F1–4, R4:1, R4:2, Advisor, Sunnersta Herrgård 18 February 2005.

development of the research process in WP 4 were taken. Tables 3 and 4 present the outcomes of tools for evaluation and/or grading, used to facilitate discussion on how the group had met its goals and how the different activities had contributed.

In the timeline in Figure 4, the researchers of WP 4, the advisor and the study coordinator have illustrated their assessment of the importance of the key decisions taken, in terms of how the process developed, when made and by whom.

Cooperation and understanding

This section presents findings of a different kind: the relations that arose within the research team and between the researchers and farmers as a result of incorporating the participatory activities. The role of the facilitator's contribution to the research and collaboration was questioned as she tried to understand and facilitate the development of these relations, something not often done in natural science projects.

At the start of WP 4 it was stressed that the focus in PLAR is not on 'solving' well-bounded problems, but on improving 'messy' management situations that require farmers to adapt 'best bet options' to the particularities of their own enterprise, growing conditions, market opportunities, etc. It was pointed out that the effects are achieved through collaboration between actors with different experiences and knowledge related to a shared area, theme or

Table 4. Group grading and comments on contribution of different activities (modified for publication).

Activity	5	4	3	2	1
Group meetings		Could have been better. Sometimes ineffective, when we came unprepared, but all engaged to a certain degree. Traditional of roles. Other processes take time. When are they proper?			
Study meetings		Good! But 1st meeting ... We did not know where we, [the farmers] came in.			
Practical discussions			Too little time for this		
Individual work		A1 has been work leader. Own responsibilities give good participation. We have had time [to do our tasks]! Made other farmers curious.		Good start.	
Tools, exercises		Gives structure to the work. Raises questions. Good start. Some better than others.		Do not understand how it contributes.	
Field trips	Really interesting. Gives other dimension to discussion when in the field.				
Telephone meetings			Only to make decisions, check practicalities. Effective but boring.		
On farm visits by Researchers and advisor	Raised good discussions. Plenty of time! Farmers: Nice to focus on own production. Researchers: Really nice to come.				
SWOT			Difficult to understand. You had to 'wrinkle your brain'.		
Visits by researchers on group meetings	Really good but too little. Compost discussion was interesting. Interesting though difficult to understand. But we [farmers] understand where they [researchers] want to get to.				

Source: F1–4, R4:1, R4:2, A1, Sunnersta Herrgård 18 February 2005.

topic of interest, aiming for practical change as well as new knowledge[11,12]. The participants either agreed or did not contradict the proposition that the quality of the collaboration would be important to achieving the desired outcomes and that care would have to be taken to adjust the process as it unfolded 'in real time'. It was recognized that this would demand a commitment to consistency in attendance at key events and that time should be set aside at key moments throughout the process for joint reflection and re-planning.

The information in Figure 4 indicates that the participants considered the most important decisions influencing the whole process were those taken at the time of planning the study and writing the application. It was at this early point before the participants had met each other that the main research questions were set and the criteria were set concerning which farmers to invite. It was noted that the facilitator had joined the process at a later stage and had no influence on the process aspects of the study design.

Relations within research team. The responsible researchers for each of the other three WPs were interviewed by the facilitator on their experiences of having a participatory group included in the research design. They expressed a range of views:

> One was generally positive and stressed how nice it was to get to discuss subjects with farmers who '*are not within your own sphere, but know the subject*' (R2:1, 24 May 2005).
> Another expressed criticism: '*They* [the participatory group] *have missed a chance by not doing repeated trials, this is not usable scientifically*' (R1:1, May 05). This researcher would have liked to see identical trials carried out at every farm. But the researcher also stressed the importance of the PhD students (who had a biology background) involved in her WP, having a chance to meet farmers.
> The third had developed an active relationship with the farmers through discussions initiated at a visit to a participatory group meeting and when taking samples from the farmer trials. The idea of using the farmers' own produce as samples came from this researcher who saw increased possibilities for the researchers' disciplinary research through the participatory group. The researcher had had earlier contacts with another participatory farmer research group and was very positive towards the idea from the start. The researcher said: '*I have learned that reality is really important for the research, to really get a dialogue with farmers that is providing. It is a really important question, very exiting*' (R3:1, 17 August 2005).
> The study coordinator and two of the interviewed researchers pointed also to the importance for researchers of experiencing the interest and request of their knowledge from the research receivers. The researcher said: '*It is fun to get to hear that some people enjoy what you are doing, that happens extremely seldom*' (R1:1, May 05).

Two of the three interviewed researchers stated or implied that the participatory group's inclusion in the program had not had any effects on their research.

Relations between research team and farmers. The researchers participating in the group collaboration gave only general answers when asked about what they had learned from the collaboration that might be of use for their personal future research. They expressed enjoyment of the new experience of working with farmers and said they had gained increased insight into the farmers' situation[10]. The advisor pointed to the importance of the experiences generated under WP 4 relating to other contexts when explaining farmer practices to decision makers and other actors. The advisor also commented on the difficulties of doing PLAR while positioned in a predetermined and time-bound project.

Researcher 4:1 and the advisor claimed to have learned '*quite a lot*' about mulching (Sunnersta Herrgård, 18 February 2005), both from the research station trials but especially from two of the farmers' trials. The farmers both had a long experience of mulching and had developed their own systems and equipment to make the practice work. One of these farmers, F4, had expected to learn from his participation in the study detailed quantitative facts on the rate of degradation of the material, microbial life, effects on quality and such. He was disappointed that these questions remained unanswered at the end of the collaboration.

The presence of researchers from other WPs at the group meetings was experienced as: '*really thrilling*' and '*very good*'. The farmers would have liked there to be more such visits yet mentioned a constant lack of time for meetings as a deterring factor. The contact with the different researchers was described as '*the bonus of this project*' (Sunnersta Herrgård, 18 February 2005). Farmer 2 describes what a '*kick*' it was to discuss things with researchers and sort out sticky problems together and thought all farmers ought to get the chance to have that experience. This farmer's openness to learning can be exemplified from a field trip to a research station (Krusenberg, 04.08.21) where he got inspiration from the researchers' trials on incorporating mulching in the soil. During the group's visit to his farm on the very next day he had tried already to incorporate a small part of what he had learned into his own system.

All farmers present at the evaluation concluded that the researcher contact was something they would like to have continued access to, although they found it difficult to understand the researcher presentations at the common large meeting. One farmer commented on this, saying '*Sometimes they go into things so deeply; it is difficult to understand what they are looking for.*'(F6, March 05). When the farmers wanted to know whether their participation had contributed to the researchers' work, the coordinator expressed the importance of having the possibility to relate one's research knowledge and other information to the practical context.

Discussions during the two common field trips were mutually enriching, as illustrated below (Krusenberg, 04.08.21, facilitator notes).

> Farmer 4 pointed to the effects of non-experimental variables in the trials by questioning whether the good growth observed in the plot was because the ploughed-in ley gave relatively high levels of nitrogen. He said: '*We always see that* [the effects of good soil structure] *and it is always forgotten*'. A discussion on

Figure 5. The 'rich picture' from the first meeting (F1, 2, 5, 6 Sunnersta Herrgård 4 March 2002) (Copied and translated by author).

the need for measuring root length started. It ended with the conclusion that such measurements would have been nice to do but that there is no funding for such a time-consuming task. At the next plot, to which digested sludge had been applied and growth was poor, farmer 3 said: '*Well this doesn't work.*' meaning that it would be of no use in practice. Researcher 1:3 standing nearby answered the farmer with a neutral prompting question: '*no?*'. The farmer continued: '*You should give digested sludge to the plough-in now*'. A discussion began on the possibilities of how the different treatments could be combined. Later that night the researcher 4 : 1, who was also responsible for the research station trials, concluded that the real purpose of the trials was to develop knowledge on the basics of the research variables, and that the issue of combined treatments is something that could be done subsequently (in a some other project).

The farmers several times brought up questions related to environmental issues. They wanted to know, for instance, more about the factors causing nutrient leakage, and the energy consumption involved in each manuring option. The study team repeatedly responded with statements of regret that it was not possible to include such questions, as the funding agency had not accepted the WP related to the environmental aspects.

The role of the facilitator: a problematic position. At the first meeting, the facilitator introduced a tool for situation analysis: drawing a 'rich picture' (Sunnersta Herrgård, 4 March 2002) of what was thought to have impact on the farmers' cabbage production, as a prompt for discussion of different viewpoints and priorities. A few farmers drew something on the paper, not really listening to instructions and without much enthusiasm. The resulting picture (Fig. 5) shows a few unconnected illustrations; the farmers may have realized that the participatory determination of the focus area of the study was redundant since the boundaries already had been decided in the original research application. The facilitator considered the exercise a failure, the picture was not much discussed and the tool was not used again during the study.

The participants' stated goals all stayed within the limits set by the aims of the research study. So did all the questions expressed in the matrix table produced at the third meeting. The facilitator's own self-reflection on the process at that time included:

> Is there a need for working with group dynamics, in order to broaden the context and expand the area of interest? (Given that the tasks of the group were already set by the study design). How to deal with the conventional pattern of interaction, with the researchers giving suggestions on what to do, and farmers asking for suggestions? (Facilitator's diary, April–July 2002)

The research application had claimed that the study would be 'participatory driven research'. The farmers had been introduced to this phrase when invited to participate. When the facilitator was invited to join the project, the written application described PLAR as an evaluation method. The study coordinator pushed for improving the '*qualitative experiences*' in the project. The advisor responsible for the WP had, together with the facilitator, worked in a PLAR group before. Discussions between the facilitator and the study coordinator and advisor resulted in a decision to work for as 'high a level of participation as possible under the circumstances'; the meaning of this phrase was not further discussed. For the facilitator, it implied a process of 'striving for' this goal, i.e., collegial decision making on what situation was to be improved, what questions were to be asked and how they should be explored, analyzed, concluded and presented. The participants agreed to the general aim during the second meeting of the group, influenced by the fact that the farmers had clearly stated in the negotiated group contract that each member should take an interest in each farmer's trials and research questions.

The facilitator had been requested by the program coordinator to prepare a written article on the process and trial results. The initial intention was that this should be co-authored together with the advisor and researchers (R4:1, R4:2, SC), and published under all WP 4 participants' names as a way of acknowledging the essentially collective nature of the enterprise. The writing turned out to be problematic: roles, process and content all proved contentious. The status of the article was 'down graded' to a report[10]. In the end no one had anything to add and the facilitator remained the sole author.

Table 5. Participants' reflections following the use of the different manuring strategies.

Material	Reflections
Pelleted poultry manure	Gave high yield responses in small doses, which could be due to added S that in other treatments were low.
Compost	Reactions to compost depended on how well it fitted into the farm system and according to levels of difficulties of getting local manure. Difficulties with good chopping and keeping nice moisture were experienced.
Mulching	Spreading the material was work demanding and weather dependent. A farmer had already constructed his own machinery for the task and kept the work load down. He experienced reduced levels of weeds.
Digested sludge	Lack of equipment, spreading with water cans was tiresome and gave burns on the crop. Also the fungus *Alternaria* increased. Did not give the expected nutrient boost.
Intercropping	Introducing annual crops in the spring was difficult. Red clover established the year before gave half yield and the double amount of work. Quality was nice with low damage from pests.
Ensilage	Gave compaction damage when ploughed and ammonia lesion when used as mulching under a cultivation cloth.
Ploughing in of ley	The ploughing in of harvested or unharvested ley had a large impact on the results. When left unharvested, the ley gave larger yields. Farmers in general knew this prior to the trial but came to appreciate better the importance of tending to the ley.

Source: End report to funding agency, The Swedish Resource Council Formas, n.d., and Sunnersta Herrgård 18 February 2005.

Analysis and Discussion

These findings lead into discussion of two challenges that surfaced during the project. The first has to do with the robustness of the data generated. Questions were raised about the role of the PLAR WP as a disruptor of conventional research trials, leading to impure data that could not be analyzed using conventional methods: in brief, the loss of methodological rigor led to a 'failed' research outcome. The second had to do with the 'stability of the research object'. The PLAR process stimulated the participants to observe, measure, analyze and learn, leading to changes in both understanding and directly to changes in the on farm practices. These two challenges prompted the team to query the whole enterprise: was the 'bastard' design, mixing conventional and participatory elements, fit for purpose? I address each of these challenges in turn.

The outputs of the overall study were reported at a Nordic Association of Agricultural Scientists seminar (posters 6–10[13]), focusing on forms of green manure, changes in soil bacterial community, soil content, intercropping issues related to insect pests and options for handling competition with the main crop. Other results published[14,15] focus on the impact of fresh green manuring material compared to digested, and on the difficulties in quantifying carbon flows because of the higher heterogeneity in farm fields compared to controlled laboratory experiments.

In the end report to the funding agency, the only quantitative result presented from WP 4, though not statistically proven, was that plough-in of mature ley gave a production increase to the next cabbage crop compared to plough-in of harvested ley. At the evaluation day, all participants agreed on R 4:1's comment on this finding '*We already knew before, that green manuring* [in this case plough in of ley] *was great . . . and we still know that*'. And farmer 1 added '*You could not participate if you didn't know that!*' – which the advisor agreed was correct (Sunnersta Herrgård, 18 February 2005). So, quantitative results from WP 4 can be said to be nil.

However, we argue that this failure does not amount to a claim that reliable knowledge was not generated. All farmers at the start of the project shared a concern about their reliance on an imported pelleted poultry manure product. By studying Table 1, we can see that the most positive farmer, F2, only carried out trials on the basis of ploughing in of the full ley crop. F3 based almost all his trials on harvested ley; F4 also based his trials on harvested ley; the ones he based on full ley were the trials on mulching and intercropping. These proved problematic and did not yield the learning he had expected. From the facilitator's perspective, it was clear that these two farmers had tried alternatives that did not, or could not, fit their existing system. The farmers concluded that the project appeared for them simply to have proven the necessity of using the imported pelleted manure product. F5 had undertaken only the trials based on harvested ley, but he did not come to the evaluation and did not respond to request for a follow-up interview. F6 said he had learnt about mulching but did not mention his own trials during the evaluation. F3, 4, 5 tried harvested ley with no extra treatment which, especially for F4 with light soils, caused financial losses. From a researcher perspective, these manuring trials were judged by R 4:1 to be equivalent to treatments that yielded reliable results (Sätrabrunn, 21 August 2004). Although this assessment must be modified by the fact that no measurements were taken of the material added, it could be argued that the varying judgements on what results the on-farm trials produced are essentially differences in claims about what is effective knowledge in relation to a purpose.

The experience further indicates the different weight scientists and facilitators give to knowledge as an end product and learning as a process of knowledge generation. An examination of the information in Table 5 shows that

though learning has been going on, there are not many results that the participants together could not have foreseen. The farmers commented that actually they did not know if any of the results were relevant because the results were presented independently of information on the environmental context. They especially asked for future studies to take account of energy consumption of alternative practices (Sunnersta Herrgård, 18 February 2005). These comments link to the literature on innovation systems[16,17] that emphasizes '*working with and reworking the stock of knowledge is the dominant activity in innovation*'[18]. It also links to work[19] that distinguishes an epistemology of possession (knowledge that can be built, owned, circulated and used for innovation) and an epistemology of action (knowledge that is produced during the process of acting).

Analysis of the findings further highlights a number of organizational issues. The implications of having a PLAR WP added to the project were initially not clear to the participants in the planning group. While, for instance, the advisor envisaged that farmers would play a driving role in the overall execution of the WP, the researchers, who were unfamiliar with PLAR theory and processes, envisaged a more conventional division of responsibilities that left scientists in control. PLAR in early study descriptions was called both a 'method' and an 'evaluation model'. The WP 4 advisor, and later the facilitator, brought into the planning process additional information, experience and theoretical knowledge related to trans-disciplinary, symmetrical, systemic research. In some instances, the initial reaction from scientific colleagues to these contributions tended to be dismissive or explicitly negative. Right from the start, connecting the PLAR activity to a conventionally framed scientific study turned out to be rather difficult and controversial.

As the work progressed the issue of 'knowledge possession' was revealed in the way the work was organized. For instance, the farmers' trials and fields were used by researchers in WPs 1–3 for collecting soil samples, checking pathogen frequency and measuring quality parameters in the cash crop (cabbage). The farmers were also asked to suggest the levels of manuring that should be used in the research station trials, about how to develop appropriate machinery, cash crop varieties for the research station trials as well as to identify the crops that could be of interest in the intercropping trials. Thus, the researchers drew extensively on farmers' knowledge as an input into their own work.

In the on-farm trials, we do not see a simple symmetrical reversal, with farmers using inputs from researchers to drive their own experimental work. The plans for the on-farm work were drawn up by the researchers. When the plans were presented to the farmers, they had plenty of questions and comments. Their ideas and viewpoints were aggregated into 20 sub-paragraphs in the meeting memos. The items listed and the general discussion can be clustered into different categories: (1) those that accepted the framing as a given but raised questions of implementation, like lack of necessary equipment and varieties of crops that would fit their systems; (2) those that sought to extend the boundary of the innovation space by raising questions like '*Could not the intercrop be cut in the middle of the season and be used for mulching?*'; and (3) questions that challenged the researchers' assumptions about the purpose of the trials in relation to the farmers' own systems, such as how to organize the flow of nutrients among farmers who had access to horse, poultry and cattle manure, compost from fungi production, or discarded ensilage and those who did not. The organization of the work in this project meant that, whatever the claims and intentions, the third category simply could not be included in the overall study. Farmer 2 actually did try composting horse manure, a main reason for his contentment with the project, but this was not reported among the trials in the end report to the funding agency.

In addition, it is clear with hindsight that there was insufficient attention paid to farmers' decision making and management roles. The farms were not simply a *site* for a particular kind of activity, namely on-farm trials, but dynamic contexts purposively managed through time and space to capture market opportunities. 'Reading the context' from different perspectives proved a challenge. Although the advisor and researchers visited the individual farms on numerous occasions, several of the on-farm trials proved quite problematic from their point of view. The problems from the researchers' perspective included missing and broken equipment, late planting, ammonia damage on leaves, bird damage, time-consuming new procedures, heavy work, etc. From the farmers' perspective the challenge was more a question of how to manage the trials in a context of their ongoing decision-making and systems management processes. Eventually the farmers concluded that they could not evaluate the economic performance of the trials. There were too many first time problems and farmers had not had time to learn how to manage the options and adjust their management and working practices to accommodate them.

Catalyzing changes in the farm enterprise

In a discussion of changes and developments on the farms during the trials, one farmer said the following;

> We have all done that, you catch a bit here and a bit there and mix them according to your own circumstances and views, and then you do not need to make all the mistakes (F3, Sunnersta Herrgård 18 February 2005)

His meaning was, this is the normal way we learn how to improve our practice, i.e., knowing in action. In order to clarify more exactly what changes on farm had been catalyzed by the project, a discussion tool was used, pictured in Figure 3a and b. This was complemented by an in-depth interview with one farmer. The farmers' perceptions of the main changes are presented in Table 6. The farmer on farm 2

Table 6. Changes on farm arising from the group collaboration.

Farm 1	On this farm there would not be changes within the near future resulting from the group collaboration. All the ley they produced was used by a dairy producer that they collaborate with. The collaboration might be changed because of a greater evolution of Swedish agricultural policy. The need to produce green manure may arise, in which case the learning from the group collaboration would be used.
Farm 2	This farmer had during the year reached his goal of no longer having to use pelleted poultry manure. He had instead composted ley and horse manure from near-by stables. He had now an alternative he had not seen before. This also meant that he has decreased his acreage of cereals as; '*it is better to put the costs on the ley* [that pays off]'(Sunnersta Herrgård 18 February 2005).
Farm 3	This farmer said that he was going to reduce the use of pelleted poultry manure through increasing the direct plough-in of ley: but added that he had been planning to do this, in any case. He claimed that he had learnt valuable information about details and increased his understanding of managing the ley crop.
Farm 4	This framer planned to reduce his import of cow and poultry dung to the farm and use more of his own ley (which at the time was sold off the farm). He also planned to increase his acreage of green manuring and decrease the potatoes. He claimed that he already knew how to improve his system but that the collaboration had strengthened his position.
Farm 5	This farmer had made changes to reduce the amount of imported manure before the collaboration and he continued this practice. (He did not attend the evaluation day and has not been available for an interview.)
Farm 6	This farmer did not use green manure before taking part in the project but decided to start using both direct ploughing in ley and mulching. He claimed that his views on green manure changed from '*none at all*' to wanting to produce some of the needed nutrients on farm (interviewed March 2005).

Source: Sunnersta Herrgård 18 February 2005.

said that he had come much closer to developing a farm system that runs on the available local and regional nutrient resources. This farmer expressed clearly that he wanted to develop his '*farm system*'; a system that is fun to manage, profitable and does not demand the performance of many unpaid chores, i.e., he was seeking systemic improvement rather than problem-solving knowledge.

We can see clearly reflected here that it is not enough for scientists who seek to support ecological agriculture to understand learning as 'situated in practice', and 'on-farm trials' as a sufficient practice to provoke transitions in understanding and system management. If a farmer tries something that is not of interest to his system, the only thing that will be learnt is that it was not of use to his system, and there will not be any catalyzing effect from a project intervention. For example, farm 1 had selected composting ley from the suite of on-farm trial options, a practice the husband and wife on farm 1 themselves judged as follows '*composting ley is absolutely mad on our farm*' (Sunnersta Herrgård 17 February 2005). Their own idea of composting spoiled ensilage (for them, an easily accessible resource) was not included in the trial options. This in turn raises an issue of increasing importance, not only in organic horticulture but also in wider societal debate, on how to assist agricultural sectors to move toward agro-ecological sustainability. What is at stake for the scientific community is researchers' preparedness to place their knowledge and practice in society in ways that catalyze the transitions that seem to be needed.

The methods and approach: were they fit for purpose?

In this section, we discuss briefly a response to the key questions for this article. At the time of planning and initiating the study, when the most important decisions for the development of the process of the PLAR group were taken, a disciplinary-based natural science research approach was taken as the standard. There did exist an understanding of the need to find solutions to practical problems on a broader base than purely disciplinary or single-factor studies, and that the research process needed to come into more contact with production practices in order to deliver results relevant for farmers. This was the basic motivation for inviting farmers into the study. Yet from the start the project contained a hidden controversy. The questions to be studied were focused on well-defined variables, bounded by the researchers' understanding, planned as discrete activities and constructed around quantitative researcher-designed and -managed trials. Thus, in WP 4, quantitative trials were planned for qualitative goals. It is revealing that at the end of project the participants of WP 4 were talking about quantitative 'trials and research' and contrasting them to qualitative 'work'.

Although there was an awareness of the importance of developing a fuller picture through a more systemic approach, it was assumed that this could be achieved by connecting the parts once the study had been accomplished. The project claimed to be 'working with systems', but there was no formal description of what 'the systems' were, how they could be conceptualized or how they should be analyzed. The systems to be studied were 'bounded down', i.e., restricted to a selection of manuring strategies that were claimed to be multifunctional 'tools'. But there was no explanation of, for instance, how digested sludge could be a tool against weeds and pests. The effort to build a systems model from the results of the component parts of the project was never formally completed by the end of the project.

Within a 'participant driven' PLAR approach, the farmers would have been invited to explore a wider area

of interest, like organic vegetable production or nutrient management in organic vegetable production. The focus would have been developed thereafter on the basis of shared interests between the participating farmers as well as the researchers. However, in this case, the relevance to farmers was assumed to be secured through the possibility of choosing one more additional treatment to those already planned. In striving for relevance, the farmers had additional opportunities to carry out adaptations on their farms, involving changes, subtractions and additions to the design of the trials. During this process, the trials gained in systemicity as they were adapted to real farm systems, but they lost systematic rigor and as a result of the increasing diversity and by management decisions that departed from conventional scientific standards. It proved impossible to implement well-functioning trials when, without reflection, there was pressure to merge the intentions of two approaches, i.e., when objective, single-factor trials that could yield data for augmenting research knowledge, were conflated with trials progressively adapted toward systemic research aiming at situation improvement. To deliver the first would require negating the second aim; to deliver the second would re-position the first aim as a by-product of action-based learning.

The differences between the research approaches and between the methods used for implementation became clear in writing up the work of WP 4. For instance, distinctions were drawn between presenting the process of researching in order to understand farmers' agronomic practices, reporting scientific trial results and relating the experience of trying to facilitate and carry out PLAR. The writing brought many of the contradictions presented in this article to the surface. It became evident that allowing the 'failures' in the scientific aspects of the on-farm trials had been necessary for researching and learning in the participatory research process, and were needed to generate outcomes relevant for the aims and goals of organic farming.

Another way of considering the 'fit for purpose' question is to reflect on the new relationships that were constructed through the project. These undoubtedly produced moments of high connectivity, such as the meeting on 6 April 2004 when each participant had an opportunity to present and discuss his or her own experience of what they had learned from the project. Yet, the project also served to disconnect, as the evaluation process demonstrated, the different ways of acting, learning and knowing.

Farmers' knowledge and skills were meant to be used to evaluate the research questions already decided on, not contribute to the process of defining the research or the criteria by which outputs and outcomes were evaluated (contrast this to Bonny et al.[20]). Thus, the project clearly signalled an asymmetry in the way in which different kinds of knowledge, and of knowledge-generating methods, was valued. These differences in valuation of different knowledge, also described in Eshuis and Stuvier[21] were instanced in many small events. For example, the steering committee scheduling trial planning on the very day WP 4 was initiated, and the WP 4 evaluation day was scheduled after the formal 'sharing of results'.

Within WP 4, farmers' skills and knowledge were well used in a symmetrical process of learning, and appreciated. But at times, both within WP 4 and in the overall study, a very hierarchical relationship prevailed. To put it bluntly, the advisor gave plenty of approving feedback to the farmers for their contributions and work, the farmers expressed how much they valued the discussions with, and visits by, the advisor and researchers, while the researchers, both in the WP and the study, commented on how much they appreciated feedback from the research receivers on how interesting their research was. Researchers 4:1 and 4:2 when asked what they had learned from the study mentioned mulching, i.e., the manuring strategy that the farmers added, but at the same time, they did not mention that they had learned anything of importance for their own research (Sunnersta Herrgård, 18 February 2005). Interviews with the researchers who had asked for farmers' opinions and listened to farmers' reasons for making a particular combination of treatments or the problems of adapting trials for their own systems, failed to elicit any reference to systemic understanding or to shared learning even though the study drew on the farmers' knowledge to decide the treatments and the crops selected for the research station trials.

Conclusion

Scholz et al.[22] discuss how trans-disciplinarity sets science on *'its head'* because its practice demands researchers move from the screening of a problem within a narrow theoretical perspective to identifying where in a messy situation their competence might contribute. It is concluded that this is not an easy change and it takes time to relate the contextual knowledge of farmers to the abstract knowledge of scientists. The conventional assumption of a hierarchy of knowledge in which truth, natural law and empirical tests of an objectively knowable universe stand at the apex, places lived and felt experience and contextual knowledge grounded in practice at the un-regarded base of the hierarchy. PLAR seeks to introduce greater symmetry in knowledge claims and the rigor of knowledge-generating processes, by means of procedural and relational changes. Yet, as this article evidences, PLAR as an add-on WP cannot hope to catalyze such transitions or instil lasting change. At best—which this article also evidences—it may catalyze temporary changes in procedure and relationships that open up spaces for shared learning. Research needs to be adapted to the systemic characteristics of the sustainability problems. This is needed to ensure that outputs and outcomes will contribute to improving agricultural sustainability.

It is a real pity that the strong competition for funding and need to do 'good research' to qualify in the research community makes it difficult to share such problems and 'failures'. Without a conscious knowledge, awareness and

trust of the each others' capabilities, and a collaborative environment where failures can be shared without fear of being judged, such collaboration will continue to be disappointing. This will affect the aims of gaining holistic understanding to facilitate transitions to reach the goals of improved sustainability.

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Green food industry in China: development, problems and policies

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Abstract

Organic food is the development trend of food in the world today. China's green food is a kind of food with pollution-free, safety, high-quality and nutritious properties, similar to organic food in the international market. The Chinese government has paid attention to the sustainable development of agro-ecosystems under the pressures of population growth and agricultural expansion since the 1980s and began to develop a green food industry in 1990. After the development of about two decades, now the Chinese green food industry has already entered a fast-growth stage. It has reached a considerable scale and is expanding rapidly. The share of green food in the global market is continuously increasing and a two-tier certification system has been established. However, green food's further development is still facing some difficulties and problems. This paper mainly analyzes those problems and discusses reasonable solutions. Specifically, this paper first gives a detailed introduction to green food and the green food industry in China, and then analyzes the major problems impeding the further development of green food industry, such as unreasonable product structure and enterprise structure, incomplete market system and backward certification system. Finally, suggestions on product structure, enterprise structure, publicity, market, certification system and governmental policies are put forward.

Key words: green food, green food industry, sustainable agriculture, policy, China

Introduction

Since the 1960s, global environmental problems have become increasingly prominent and pose a grave threat to human survival and development. A wave of promoting a coordinated development of economy, resources and environment is sweeping across the world. Issues about environmental protection and sustainable development have become hot topics discussed by governments and people worldwide. Organic agriculture and organic food have attracted increasing attention as being environmentally sound[1]. Organic agriculture originated from a notion of 'working with natural systems rather than seeking to dominate them'[2]. According to EU regulations organic farming entails significant restrictions on the use of fertilizers and pesticides which may have detrimental effects on the environment or result in the presence of residues in agricultural produce[3]. It advocates safety, pollution-free and environmental protection and seeks harmonious coexistence between humans and nature, not simply placing emphasis on efficiency and effectiveness. So it is often viewed as a superior system for the environment, soil, livestock and the humans who work in it[4] and as an alternative production system by conventional farmers[5]. Organic food is the product of organic farming and perceived as being healthier and less damaging to the environment. Organic food's quality is high. According to the Food and Agriculture Organization (FAO), food quality refers to positive attributes (e.g., nutritional values, origin, color, flavor, texture and production/processing method) that influence a product's value to the consumer and the absence of negative attributes (e.g., spoilage, contamination with filth, discoloration and off-odors). Over the past few years, some developed countries, European countries in particular, have paid much attention to organic agriculture and organic food, and created a series of preferential policies to encourage conventional farmers to change toward organic production. In 1972, the International Federation for Organic Agriculture Movements (IFOAM), the biggest and most authoritative organization of organic agriculture in the world, was set up. IFOAM has been committed to protecting ecosystems and developing healthy and safe food, greatly promoting the development of the organic food industry. In recent years, some highly publicized outbreaks of food-borne diseases, such as mad cow disease and H5N1 killer flu have brought food safety and associated issues to the forefront of societal

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concerns[6]. Under these circumstances, people attached more importance to organic food because of its pollution-free, safe and healthy properties. Today, organic food is developing very rapidly in developed countries and has become a trend of food for the future.

Green food is a kind of food featuring pollution-free, safety, high-quality and nutritious content[7]. The development of China's green food is the outcome of actively exploring new ways of food production and consumption based on China's national conditions and in line with the international trend of sustainable development. Since the 1980s, increasing environmental pressure has posed serious challenges to China's agriculture as a result of population growth and agricultural expansion[8]. Influenced by the thought of sustainable development widespread in the world, the Chinese government began to pay attention to sustainability of agro-ecosystems. The agricultural policies and production process in China gradually changed and attached more importance to environmental protection[9]. Meanwhile, with the rapid growth of China's economy and the improvement of living standards, the Chinese people have shown more and more interest in food quality[10]. Against this background, the Ministry of Agriculture (MOA) began in 1990 to develop green food throughout the country. In the same year, the MOA initiated the Green Food Program and in 1992 established the China Green Food Development Center (CGFDC) responsible for national green food development. Over the past 10 years or so, consumption demand for green food in China has been growing steadily; in particular, the frequent outbreaks of food safety incidents in recent years have made the urgent need for more green food evident and accelerated green food development[11]. The fundamental objectives of developing green food are to protect ecological environments and enhance food quality and safety. Besides, in China, green food bears the additional expectation of promoting the development of rural economy and increasing farmers' income[12]. China is a large agricultural country with a dominant rural population. Many rural people, little arable land, comparatively inadequate per capita share of natural resources plus a relatively backward agricultural productivity—these features spell out China's basic national conditions. Now, China is still economically backward in many rural areas and the proportion of poverty-stricken people in the total rural population is still high. So, promoting all-round development of rural economy, increasing the income of farmers and reducing the rural poor population are always the substance of China's rural policies. The development of green food has provided opportunities for the solution of China's rural problems. The development of a green food industry in China has played an important role in increasing agricultural productivity as well as the Chinese farmers' income, fostering agricultural restructuring and speeding up the construction of comparatively well-off villages[13]. According to statistics, the per capita income of rural people in Heilongjiang Province will grow by 1% when the total output of green food increases by 10%. In 2004, the per capita income from green food was 866 RMB yuan, accounting for 29% of per capita income of rural people of the whole province[14]. Many local governments have regarded the green food industry as a new economic growing point and formulated relevant policies to encourage farmers and food enterprises to develop green food[15].

Today, China's green food industry has already entered a fast-growth stage, but there are some problems still restraining the industry from further development, weakening its international competitiveness and negatively affecting rural development, such as unreasonable product structure and enterprise structure, certification system not conforming to international standards, incomplete distribution channels and people's lack of awareness. The aim of this paper is to make a further study of these problems and discuss reasonable solutions. This paper gives a specific and thorough introduction to China's green food industry, and then makes an in-depth analysis of the factors impeding the development of the green food industry. Finally, suggestions on optimizing product structure, intensifying publicity, widening marketing channels, improving the standard system, increasing support for policy and funds and promoting enterprise combinations are also put forward.

About Green Food

According to Liu[16], green food can be defined as 'unpolluted, safe, high grade and nutritious food that is produced by adopting special production methods in line with the principle of sustainable development, and is certified and approved by special institutions to use the green food logo'. Here 'green' figuratively represents the properties of pollution-free, safety and healthiness. The fundamental objectives of developing green food are to enhance food quality and safety, to promote consumers' health, to protect ecological environments for sustainable development and to enhance the international competitiveness of Chinese agricultural produce. Quality control of green food is very strict. First, the production areas of green food must have favorable ecological environments. An area can be selected as a production base of green food only when it and its surroundings are evaluated to be safe and unpolluted after strict environmental monitoring; second, a quality standards system from farm to table has been established. The quality of products and production will be strictly inspected and controlled according to relevant quality standards. The green food logo is a specific identifying tag, only used by those green food products having green food certificates. This is a registered trademark protected by Trademark Law of the People's Republic of China and under the unified supervision of CGFDC. In China, green food has been classified into Grade A and Grade AA since 1996. The definition of Grade AA green food[17] is as follows: it is a kind of food that is certified and approved by special institutions to use the logo of Grade AA green food; environmental quality of its production

Table 1. Comparison between Grade AA green food and Grade A green food[18].

Items compared	Grade AA green food	Grade A green food
Environmental standards and evaluation of green food production areas	The environmental standard is Standard NY/T391. Environmental evaluation uses the monomial index method that all the monitoring data must be within the prescribed limits	The environmental standard is Standard NY/T391. Environmental evaluation uses the integrated index method that the integrated pollution index of all the monitoring data must be lower than 1
Standards and evaluation of production process	Production process standards include 'Guideline on Pesticides in Green Food Production', 'Guideline on Fertilizers in Green Food Production' and 'Production Regulation of Green Food Production'. In the production, any synthetic compositions are absolutely forbidden	Production process standards are the same as those of Grade AA green food. In the production process, specified synthetic compositions are restricted for use by adopting special methods in limited amount and time
Standards and evaluation of product quality	Product quality must meet Industrial Standards on Green Food Products. Any chemical synthetic fertilizer and food additive must not be detected in Grade AA green food	Product quality standards are the same as those of Grade AA green food. The residue of specified synthetic compounds in Grade A green food products must be lower than relevant standards. Other prohibited chemical residues must not be detected
Package standards	Package standards include National Standard on Packing Materials and National Standard on Food Labeling	Package standards are the same as those of Grade AA green food

area meets the requirements of environmental standard and all chemical synthetic compositions, such as chemical synthetic fertilizers, pesticides, veterinary drugs, additives and other substances harmful to health and environment, are prohibited form use in the production process; it is produced by adopting organic production methods and the product quality meets the standard on green food product. For the production of Grade A green food, the use of chemical compositions is extremely restricted. The quality standards of Grade AA conform to those of organic food completely, so the Chinese Grade AA green food is equivalent to organic food in the international market. Table 1[18] shows a comparison between Grade AA and Grade A green food. The aim of this graded certification system is to provide a transition pathway for farmers to move from chemical farming to a certified reduced chemical input regime of Grade A, and then to meeting international standards for organic certification[19].

Green Food Industry in China

Administration and policies

CGFDC is the authoritative administration responsible for national development and management of green food, established by MOA in 1992. Over the past decade and a half, CGFDC has been committed to formulating policies, regulations and standards, authentication as well as quality control. It has made a great contribution to the development of green food. After years of development, CGFDC has established a nationwide working network, composed of 42 provincial and municipal branch agencies, 38 quality inspection stations and 71 environmental monitoring branches[20].

Since the 1990s, the Chinese government has paid much attention to the development of the green food industry. Up to now, a series of regulations and policies for stimulating the development of green food industry have been issued and implemented. In 1994, the words of 'to develop ecological agriculture and to adopt sustainable agricultural scientific technologies' were written down in China's Agenda 21[21]. In 2002, the Ministry of Science and Technology promulgated the Science and Technology Outline for Sustainable Development, pointing out that food safety is a key area of implementing the strategy of sustainable development[22]. In 1999, the State Economic and Trade Commission, together with seven other state agencies initiated the 'Three Green Project', with the main tasks of establishing 'green channel', promoting 'green market' and advocating 'green consumption'[23]. The implementation of the Three Green Project has improved people's knowledge about green food and greatly promoted the development of the green food industry. In 2001, MOA started to carry out an Action Plan for Pollution-free Food, anticipating that all edible agricultural produce in China will be non-polluted within 8–10 years, and in 2003 released Suggestions on Promoting Action Plan for Pollution-free Food and Simulating the Development of Green Food. In the past few years, the local governments have provided great support to the green food industry. More than 20 provinces have formulated Measures for Green Food Management[24] and Measures for Administration of Green Food Labeling[25], such as Heilongjiang, Liaoning and Guangdong. Many other local governments

Table 2. Basic statistical indicators of the Chinese green food industry from 1997 to 2007 (Adapted from China Statistic Yearbook of Green Food (1997–2007)[26]).

Year	Green food enterprises (number)	Green food varieties (number)	Annual production (million tons)	Annual sales (billion RMB yuan)	Export value (million USD)
1997	544	892	6.3	24.1	71
1998	619	1018	8.4	28.5	88
1999	742	1353	11.1	30.2	130
2000	964	1831	15	40	200
2001	1217	2400	20	50	400
2002	1756	3046	25	59.7	840
2003	2047	4030	32.6	72.3	1080
2004	2836	6496	46	86	1250
2005	3695	9728	63	103	1620
2006	4615	12,868	72	150	1960
2007	5740	15,238	83	192.9	2140
Average annual growth rate (%)	26.9	33.4	29.7	23.5	44

have also issued a series of preferential policies and award measures to promote its further development; for example, Urumqi has established funds to support the development of leading green food enterprises and green food production bases.

Growth rate and scale of green food industry

The green food industry of China has been developing rapidly over the past decade. Today, it has reached a considerable scale and expanded rapidly. As shown in Table 2[26], the five basic statistical indicators of green food industry all rose remarkably. In 1997, the number of green food enterprises, the varieties of green food products, annual production, annual sales and export value were merely 544, 892, 6.3 million tons, 24.1 billion RMB yuan and 71 million USD, respectively; however, the corresponding data in 2007 rose to 5740, 15,238, 83 million tons, 192.9 billion RMB yuan and 2140 million USD, respectively. From 1997 to 2007, the average annual growth rate of the five indicators reached up to 26.9, 33.4, 29.7, 23.5 and 44%, respectively. The industrial development continues to show an upward tendency and the industrialization process of green food accelerates obviously.

Although the green food industry of China has made great progress, the total output of green food is still low, far from meeting the growing demand of safe agricultural products in the home and overseas markets. In 2007, the total output of green food was 83 million tons, accounting for less than 7% of the total food agricultural products of the whole country. Since the 1990s, green food consumption in developed countries has been rising rapidly, with an annual growth rate of 20%[27]. The global consumption expenses for organic food in 2007 exceeded 40 billion USD[27]. The market demand is huge; however, the export value of the Chinese green food was only about 2 billion USD in 2007 (Table 2) and China's green food enterprises merely had 5% share of the global market, far behind other developed countries. So, the production scale of China's green food is still very small and needs to be further enlarged.

Regional distribution of green food production

Presently, green food production has covered nearly all parts of the country. On the whole, it develops more rapidly in northern, central and eastern China than in western and southern China. By 2007, the provinces where the number of green food enterprises exceeded 400 were all northern, central and eastern provinces, among which there were 462 green food enterprises in Heilongjiang, 417 in Liaoning, 713 in Jiangsu, 502 in Zhejiang, 418 in Shandong and 445 in Hubei[26], altogether accounting for 51.5% of the total number of the whole country; so were the provinces where the green food varieties exceeded 1000. Among those provinces, there were 1065 varieties in Heilongjiang, 1090 in Liaoning, 1924 in Jiangsu, 1053 in Shandong and 1559 in Hubei[26], altogether making up 43.9% of the total varieties of the whole country. The distribution of the main production areas of major green food has the same feature. Take green rice for instance, in 2006 there were six provinces in which the output of green rice exceeded 500,000 tons. They were Heilongjiang, Jilin, Liaoning, Jiangsu, Anhui and Hubei, among which three were northern provinces, two central provinces and one eastern province. The total output of the six provinces accounted for 82.2% of the total of the whole country. In particular Heilongjiang produced 2,497,500 tons[26], accounting for 31.3% of the total of the whole country. Besides, some advantageous industrial clusters have been established, such as industrial clusters of green dairy products in Inner

Mongolia and Heilongjiang, and industrial clusters of green tea in Hunan and Jiangxi.

Generally, the industrial development is unbalanced between different areas in China. The industrial development in northern, central and eastern provinces has more remarkable regional advantages, while green food development in western and southern China is still backward. Western China includes 12 provinces, cities and municipalities, such as Sichuan, Guangxi, etc., covering 71.4% of the whole national territory. It is affluent in natural resources and its development potential of green food is very large. Meanwhile, it is also facing serious crises of the agricultural ecological environment, such as increase of soil and water loss and land desertification. Presently, western China is still backward in economy, especially western rural areas. Promoting green food development in western China will not only help to protect and improve the environment but will also have a great effect on the rural economic development of western China[28]. Presently, green food development in western China is still backward when compared with northern, central and eastern provinces and needs further support of policies.

Products and marketing

Along with continuous growth in industrial scale, green food is improving both in variety and quality. The green food varieties rose from 892 in 1997 to 15,238 in 2007, covering all the categories in China Classification Standards on Agricultural Products. Most of the Chinese green food products are primary products and primarily processed products with low technology content. That is, they do not need very high production technology, so their added value and prices are comparatively low. In 2007, the total output of green food was 83 million tons, among which about 70% were primary products and primarily processed products and about 30% were further-processed products[26].

Presently, the domestic market is the biggest market for green food and about 90% of green food products are sold in the home market. In the past few years, since people's living standards have continuously improved and the general public have a higher awareness of food safety, more and more Chinese consumers have accepted green food and its domestic demand has shown a distinct upward trend[29]. In many large cities, such as Beijing, Shanghai, Tianjin, Harbin, Nanjing and Shenzhen, green food products are sold through various distribution channels, including specialized shops, specialized counters in large supermarkets, specialized wholesale markets and specialized supermarkets. Pukang Supermarket for Green Farm Produce in Zhongshan City and AIDI Green Food Concourse in Shenzhen have set successful examples in this area. The Chinese government has also provided great support to the development of the green food market by holding various forms of activities, like lectures, forums and regional trade fairs, further guiding green consumption and promoting the green food trade.

Meanwhile, green food export has been expanding constantly. The export value increased from 71 million USD in 1997 to 2140 million USD in 2007, with an average annual growth rate of 44% (Table 2). In the early 1990s, green food was mainly exported to Europe, America and Japan. Today, more international markets have been opened and many green food products have been successfully exported to some countries in Asia, South America, Oceania, northern and eastern Europe. About 90% of the export is Grade AA green food. This is sold as organic food in importing countries since its quality is equivalent to that of organic food. The prices of Grade AA green food are generally higher than those of the same kind of conventional foods in the international market, but remarkably lower than those of organic food. So the Chinese Grade AA green food has obvious advantages of price in the international market[30]. Grade A green food export is relatively low, although its output accounts for 90% of the total green food product. The main reason is that Grade A green food is allowed to use chemical compositions in production and is not accepted by foreign countries. The market demands of green food differ in different countries: the American market mainly imports coarse cereals; the countries of the EU often import minor grain crops (such as adzuki bean, millet, etc.), vegetables, honey products, tea and nuts; the Japanese market mainly imports rice, coarse cereals, vegetables, honey products, nuts, tea, potherbs, etc.[30]. Chinese green rice is mainly exported to Japan, Russia and East and South Asia; green vegetables are mainly exported to Japan, America and the EU; green tea is mainly exported to Japan, America, Russia and countries of the EU. Global demand for Chinese green food is increasing year by year and the supply of some green food, such as rice, vegetables, tea, coarse cereals and honey products, always falls short of demand in the international market. However, up to now, the share of green food in the global market is still comparatively low and more efforts should be made to expand the international green food trade.

Certification and standards

The green food certification system and quality standards are the foundation for developing green food. In China, green food certification is under the administration of the CGFDC. Presently, the CGFDC has established a working network covering the whole country and its major task is to carry out the work of certification. In recent years, in order to boost its international prestige, make the Chinese green food gain more international acceptance and promote international green food trade, CGFDC has spared no effort to implement an internationalization strategy and develop international certification. In 1993, CGFDC joined IFOAM, laying the foundation of international exchanges and cooperation with relevant international organizations. Subsequently, in 2003, CGFDC established cooperative

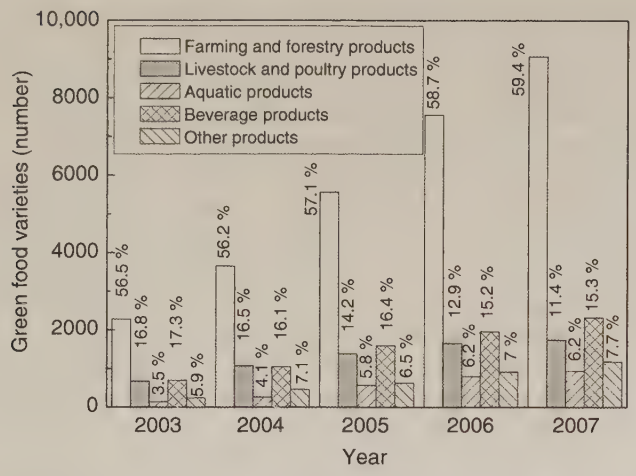

Figure 1. Product structure of green food from 2003 to 2007 (adapted from China Statistic Yearbook of Green Food (2003–2007)[26]). Note: the percentages are for the number of varieties of each category of green food proportional to the total green food varieties.

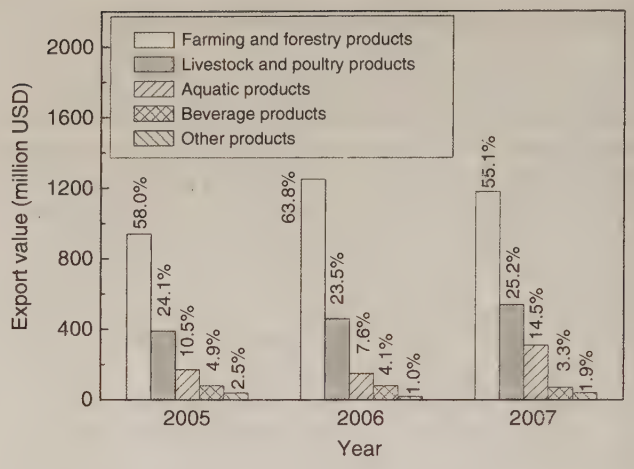

Figure 2. Green food export from 2005 to 2007 (adapted from China Statistic Yearbook of Green Food (2005–2007) [26]). Note: the percentages are for the export value of each category of green food proportional to that of the total green food.

relations with several famous international certification bodies, such as SGS in Switzerland and OMIC and JONA in Japan, and initiated international certification in 2004. Now, CGFDC has established business relations with over 90 countries and about 500 international agencies.

The green food certification system of China is a two-tier system. Since 1996, green food has been divided into Grade A and Grade AA. For Grade A, limited chemical compositions can be used while for Grade AA, any chemical compositions are absolutely forbidden can be used. The quality standards of Grade AA are formulated based on related regulations and standards of IFOAM, the EU, America and Japan, and they are completely in accordance with those of organic food in the international market. Besides, a series of quality standards have been established and implemented, mainly including environmental quality standards, production process standards, food quality and hygienic standards, package and label standards, storage and transportation standards and other production materials standards, such as fertilizer standards, pesticide standards and feedstuff and additive standards, etc. Up to now, 337 sector standards and norms for green food have been promulgated by MOA and local governments[31]. A from-farm-to-table standards system has been set up.

Major Problems

Product structure needs optimization

The product structure of green food is not reasonable and needs to be optimized. First, green food can be divided into five categories, including farming and forestry products, livestock and poultry products, aquatic products, beverage products and other products. Of all the categories, the percentage of farming and forestry products is relatively high, while the percentage of livestock and poultry products is relatively low. As shown in Figure 1[26], from 2003 to 2007, the percentage of the varieties of farming and forestry products in total green food varieties exceeded 56% each year, far higher than those of the other categories. As Figure 2[26] shows, from 2005 to 2007, farming and forestry products dominated in the green food export and the export value shared about 60% of that of the total green food products. Such a product structure is not in accordance with the food consumption pattern of developed countries featuring food of high protein and animal origin. Based on the above-mentioned national conditions of China, the existing product structure needs further adjustment. The output of livestock and poultry products needs to be raised to a proper extent so as to conform to the dietary habits of customers in developed countries, thus more market chances can be taken.

Possible trade-offs between economic and other sustainability goals is an important problem. Current production methods for animal products will lead to much higher greenhouse gas emissions, much higher water footprints and lower resource use efficiency, and diets high in animal products will lead to poor health; however, based on China's national conditions, it is hard for farmers in China to realize the environmental goals by reducing animal production at present. Adjusting the product structure and increasing the proportion of animal products is not a best choice presently, but perhaps a relatively appropriate choice for China's green food industry, because that can help increase green food export and add to farmers, income, thus further inspire the Chinese farmer's passion for more green food. If the green food industry develops more rapidly, it will contribute to the realization of environmental goals better, although not to a great degree. In spite of that, speeding up the scientific research on new production methods for animal products is the most fundamental way.

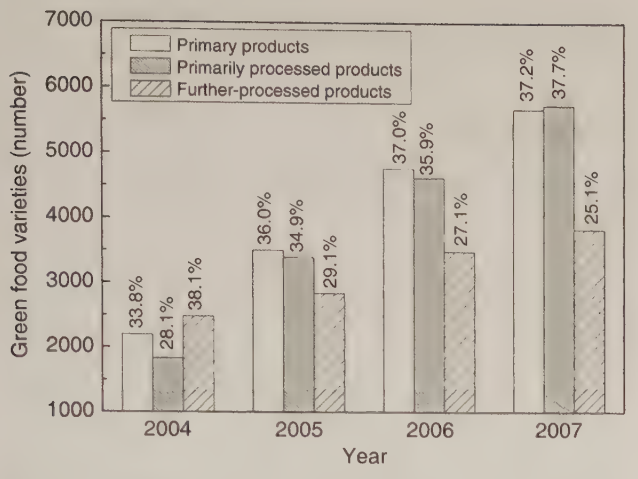

Figure 3. Product structure of green food from 2004 to 2007 (adapted from China Statistic Yearbook of Green Food (2004–2007)[26]). Note: the percentages are for the number of varieties of each category of green food proportional to the total green food varieties.

Second, the percentages of primary products and primarily processed products with low technology content and added value are comparatively high, while the percentage of further-processed products is relatively low. As shown in Figure 3[26], from 2004 to 2007, the first two categories dominated in the green food production, while the percentage of further-processed products was around 30% each year and showed a downward trend. Such a product structure has weakened the whole competitiveness of green food in home and foreign markets. On the one hand, green food products cannot compete with the conventional ones in domestic market due to unitary variety; on the other hand, lack of further-processed products and lack of diversification has become a main barrier to the green food export. Now China has the special need to develop further-processed products and increase the added value of green food. That can help to increase green food export, enhance the international competitiveness of green food, foster agricultural restructuring and increase farmers' income. That is consistent with China's agricultural development goals.

Too many small-sized enterprises and lack of leading enterprises

The structure of green food enterprises is not reasonable because there are too many small-sized enterprises and quite few leading enterprises. Although there are a large number of green food enterprises, they are generally small and there are very few enterprises whose output value can exceed a 100 million RMB yuan. In 2006, there were 4615 green food enterprises, among which there were only 240 national leading enterprises, merely accounting for 5.2%[32]. In 2007, on average, the green food varieties, annual production and annual sales of each green food enterprise were merely 2650 and 14,500 tons and 33.6 million RMB yuan, respectively. Obviously, the average scale of green food enterprises was very small. Moreover, the average scale is gradually decreasing. According to the data in Table 2[26], from 1997 to 2007, the number of green food enterprises increased from 544 to 5740, with an average annual growth rate of 26.9%; the annual sales increased from 24.1 billion RMB yuan to 192.9 billion RMB yuan, with an average annual growth rate of 23.5%, which is lower than 26.9%, that is to say, the average enterprise scale is decreasing in essence although the number of enterprises is increasing rapidly. The main reason is that the number of small-sized enterprises is increasing too quickly.

According to Zhao[33], there are two reasons for the rapid increase of small-sized enterprises: one reason is that comparatively low industrial threshold, high profitability of green food industry and preferential policies from the Chinese government have attracted more and more small-sized enterprises to enter this industry. The other reason is that some small-sized enterprises which should have been eliminated still have some living space because of local protectionism. The rapid increase of small-sized enterprises will bring about two consequences: on the one hand, inspectors and monitoring equipment would possibly be inadequate so that it is hard to ensure the quality of green food products; on the other hand, most small-sized enterprises focus on the middle and low-end market and their capability of market exploitation, scientific and technological innovations and cultivating famous brands is relatively low, so the rapid increase of small-sized enterprises will be unfavorable for the increase of industrial overall competitiveness.

Relatively low quality weakens international competitiveness

Although the green food industry is growing rapidly, the quality of green food is still relatively low. As we all know, China's green food is classified into Grade A and Grade AA and only the latter reaches the international standards of organic food. At present, less than 10% of green food enterprises have been approved to produce Grade AA green food. The output of Grade AA is also very low. In China, Grade AA green food only shares 10% of the total green food. Take Heilongjiang Province as an example, its green food industry ranking top in China, according to Statistic Yearbook of Heilongjiang Province, in 2005, the products of Grade A reached up to 5.598 million tons while the products of Grade AA were merely 44,000 tons, and honey products were the only one meeting international organic standards[15]. The output of Grade AA is so low chiefly because of the fairly strict production conditions and high production costs. Since only the products conforming to the international standards can enter into the international market, a low percentage of Grade AA will lower the international competitiveness of the whole green food industry and bring a negative impact on the export of green food.

High prices, lack of awareness, as well as incomplete distribution channels hinder the development of green food markets

Presently, although a specialized sales network has been established initially in big cities and the domestic green food market has shown a distinct rising trend, it is still a common problem that green food producers find it hard to sell their products. Price is a main reason to cause the sluggish market sales. In China, consumers purchasing green food products are much concerned about their prices. The prices of green food products are generally set very high in the supermarkets and specialized shops. According to CGFDC's market survey of 154 large supermarkets in 28 provinces of China, the prices of green food products are generally 30% higher than those of the same kind of conventional ones, some even around 1–3 times higher than those of conventional ones[32]. Meanwhile, effective demand is still insufficient[34]. For the low- and middle-income customers in China, green food products are still luxuries, while for the high-income consumers who have buying ability for green food, steady awareness of food safety has not yet been established and most of them know little about green food due to a lack of effective publicity, even including some people with high academic qualifications[34,35]. Besides, a small variety, a small output and unitary product structure make it difficult to set up stores specialized in green food and distribution channels reaching a considerable scale. Most producers and operators lack experience in marketing and have not yet set up efficient linkage between production and consumption, thus many people who can afford green food are unable to find what they want. Today, although green food markets have been initiated in big cities, lack of effective publicity and convenient distribution channels, as well as prices that are too high, hinder the development of green food markets in the other cities of China.

Backward certification standards hinder green food export

As described previously, China has initially established a two-tier green food certification system and a series of certification standards have been formulated and implemented. However, the green food standards have not been completely accepted by developed countries because some differences still exist between the Chinese green food standards and the common international standards for organic food. The Chinese green food enterprises often meet a handicap of cognition in the international trade. They often need to explain to their buyers that the Chinese Grade AA green food matches organic food in the international market. For Grade A, its standards are lower than common international ones, and the emphasis is put on the testing of finished products while strict technology and management standards for the production process, package and transportation have not been established entirely. This is the main problem hindering green food export.

Suggestions

Intensifying the readjustment of product structure

The existing product structure of green food is not reasonable, so it is necessary to intensify the readjustment of product structure and develop different grades of green food products to meet the diversified and multi-level consumption demands of domestic and international markets. First, the production of vegetables, fruits and livestock and poultry products should be appropriately enhanced to fit in with the demand of developed countries. Meanwhile, it is essential to increase added value of green food and upgrade the industry to increase the competitiveness of green food in export. The production of further-processed products and Grade AA green food needs more encouragement and support of policies. The Chinese government can increase investments in developing value-added products, or support Grade AA green food production through paying part of the certification fee for green food producers and providing organic fertilizer and bio-pesticide free of charge or at a low price. These measures have been adopted by a few local governments and can act as a model for other local governments.

Second, green food enterprises must strengthen market research and raise their capacity for product development and technological innovation. Green food enterprises should have a full understanding of the features of the market and appropriately adjust their production to adapt themselves to the changes of demand. They should also attach more importance to the development of those green food products with Chinese cultural characteristics and resource advantages so as to improve the international competitiveness of their products. Finally, enterprises should draw on the successful experience of other countries in the process of the readjustment.

Further promoting the combination of enterprises

At present, most green food enterprises of China are small and poor in capital, technologies and brands. There are few leading enterprises and famous brands. So the whole competitiveness of the Chinese green food industry is not strong. In order to improve the competitiveness in domestic and international markets, the Chinese green food enterprises should conduct collective, industrialized and integrative management and carry out famous brand strategy. On the one hand, government can support leading enterprises with coordinated and complementary products and technologies to establish large enterprise groups through conducting trans-regional and inter-departmental strategic reorganization; on the other hand, small-sized enterprises can set up enterprise groups through combination and

cooperation so as to extend their brands and enhance their ability to resist risks. The optimized modes of industrialization will be production–research, planting–breeding–processing and trade–industry–agriculture[15]. They respectively refer to integration of production enterprises and research institutions, integration of planting bases, breeding bases and processing enterprises, and integration of commercial enterprises, industrial enterprises and agricultural enterprises. The important causes of adopting these integrative operation modes are integrating various resources having complementary advantages, sharing market resources, reducing information cost and transaction cost, developing scale economy and obtaining maximal return, big enterprise driving and so on. The government may as well issue favorable industrial policies, such as providing low-interest loans or financial subsidies to support the development of leading enterprises, increasing investments in key projects to accelerate the combination of enterprises and so on.

Intensifying publicity to increase public awareness

The increase of public awareness is a huge driving force for the increase of market demand. The administrative departments and enterprises should intensify their publicity and promotion efforts to create a favorable social environment and to enhance people's awareness of food safety and green consumption. Regular publicity, education and consultation activities concerning green food should be conducted through public media, special information consulting firms or other popular means to create a good atmosphere of green food consumption gradually. Through various forms of knowledge popularization, customers will have a thorough understanding of green food. Also they will know the importance of green food for promoting good health and protecting the ecological environment; moreover, the differences among green food, pollution-free food and healthy food would be obvious. With the change of public awareness, a large market demand will be created. Additionally, in order to improve the production capacity to assure sufficient supply of green food, more publicity and guidance are needed to give to the farmers and food producers through various media to encourage them to enhance green food production. Leaders' understanding is also important, so it is essential to provide more information about green food and green food industry for the principal leaders of governments at various levels so that they would actively support the development of the green food industry.

Widening marketing channels and actively participating in international competition

Along with economic development and wide public concern about food pollution, more and more customers opt for green food. Today, China's green food has a huge market potential in both domestic and international markets, but incomplete marketing channels are still a barrier. So enterprises should strive to broaden marketing channels and more vigorously explore markets. They can use such forms as chain operation, agency systems, material distribution and electronic commerce, and give full play to the active role of modern selling methods in opening up markets. Choosing an appropriate marketing channel is very important for increasing the market share of green food. Now the customer group of green food is mainly in big cities, so green food enterprises can set up specialized counters in supermarkets, specialized stores or chain stores in big cities to occupy more market. Big cities have convenient transportation, so various types of wholesale markets and distribution centers can be established to form a nationwide sales network system. Distribution channels should be shortened as far as possible for perishable foods, such as vegetables and fruits. Direct marketing may be a good way, which can reduce intermediate links in circulation, avoid environmental pollution, lower the green food's price and increase sales.

In order to further expand green food export and increase the share in international markets, export enterprises might perform an internationalized marketing strategy. Presently, the major export markets of green food are Europe, America and Japan. The food market access systems of these countries are very strict so that the Chinese green food enterprises often encounter difficulties and risks in export. Under these circumstances, export enterprises can implement the strategy of gaining a larger market share by first-rank quality and a strategy of market diversification. On the one hand, what they could do is to further improve the export and marketing service system according to international standards, improve the export mix and expedite the export of high value added and high-grade products; on the other hand, choosing proper target markets is also very important. It would be better for small- and medium-sized enterprises with low competitiveness to choose developing countries as their major target markets for Grade A green food since the markets of developing countries are easier to access than those of developed countries. Localization is necessary for implementing the strategy of internationalization. So export enterprises should strengthen market research on local living habits and consumption styles and achieve localization of production through establishing overseas branches for product development and special industrial zones for green food. Besides, establishing good cooperative relationships with leading distributors of target markets is also an effective way to improve internationalized sales channels.

The high prices and need for more market penetration are a dilemma in all parts of the world. China's green food is not an exception. In China, green food is divided into Grade AA and Grade A. The Grade A green food products are mainly sold in the domestic market. Their prices are generally higher than those of the same kind of conventional products and much lower than those of Grade AA green food, so they are more acceptable to domestic

customers and also provide a transition pathway for China's customers to accept Grade AA green food having a much higher price. The Grade AA green food products are mainly sold in the international market. Their prices are generally higher than those of the same kind of conventional products in the international market, but remarkably lower than those of organic food. So the Chinese Grade AA green food has obvious advantages of price in the international market. Despite that, green food producers still find it hard to sell their products for many reasons, such as price, awareness, distribution channels, etc. They should make more efforts as described above.

Improving certification system and standardizing certification bodies

Quality certification in accordance with international standards is a necessary condition for green food enterprises to enter into the international market. To heighten China's international prestige of food quality certification, the administrative department must conduct extensive exchange and cooperation with relevant international organizations in quality standards, technical norms, certification management, trade rules and other fields. It is important to formulate and revise existing certification standards and technical norms for green food according to international standards, and to strengthen food safety legislation to ensure the legal status of the standards system. In order to standardize the work of certification bodies and ensure a fair evaluation of the production process and quality of green food, the administrative department should strengthen supervision through setting up an effective supervision system and improving rules and regulations on certification management, and it would be better to establish an independent third-party quality certification body in China. In addition, certification bodies must pay great attention not only to the process of certification but also to supervision and inspection after certification, thus helping to avoid a situation where some products can gain certificates but they cannot meet the quality standards when sold in market.

The government should provide more support and create a favorable policy environment

China's green food industry is still backward and it needs more support of government. The Chinese government should create a more favorable policy environment and give full support to the development of the green food industry. The policies should focus more on the following aspects. First, increasing financial support. The Chinese government should increase financial input for the introduction of new technologies, the development of new products, establishment and revision of standards, marketing and certification. Preferential industrial policies for the green food industry should be formulated and implemented to guide the application of the agricultural funds of the state toward the green food industry. Local governments can support green food production through various forms of preferential and subsidizing policies, e.g., paying part of the certification fee for green food producers, providing financial subsidies for the enterprises taking part in fairs and exhibitions, providing organic fertilizer and bio-pesticide free of charge or at a low price, or by way of agricultural projects. Government should encourage more farmers and enterprises to engage in green food production through favorable tax and loan policies. Additionally, more financial support should be provided for export enterprises, small-sized enterprises and enterprises in backward areas through reducing taxes and providing low-interest loans.

Second, attaching more importance to the development of food technology. The technology content of green food determines its added value and price, so the government should increase investments in developing new products and increase cooperation with relevant research institutions and universities so as to push the technological development of green food industry. The government should also give more support to technology innovations in leading enterprises through providing low-interest loans to new projects and increasing investments in the construction of production bases.

Third, strictly standardizing the market. Facing the problems of disorderly competition and the act of counterfeiting, the government should strengthen legislation and improve the supervision of law enforcement. It should also increase the investigation and penalty for producing and selling counterfeit and shoddy goods, so as to create a good market environment for green food.

Conclusion

Based on analyzing the status of the Chinese green food industry, this paper mainly discussed the major problems holding back its further development from the aspects of product structure, enterprise structure, public awareness, market and certification system. Suggestions on product structure, enterprise structure, publicity, market, certification system and governmental policies were put forward finally.

In order to stimulate the further development of the Chinese green food industry, enterprises and the government need to make more effort to solve the problems described previously. On the one hand, it is important for green food enterprises to enhance their international competitiveness continuously. They should spare no effort to strengthen market research, widen marketing channels and improve their capacity for product development and technological innovation; on the other hand, the push of the government is also a huge driving force. The key to solving many existing problems, such as the readjustment of product structure, the improvement of the certification system and the creation of policies and regulations, lies in the government's decisions. A favorable policy environment is fairly important. Therefore, in order to speed up the

development of the Chinese green food industry, the Chinese government needs to make a greater effort.

Besides, based on China's national conditions, developing green food is of help to environmental protection to a certain extent, such as reducing the use of chemical synthetic compositions, but some deeper environmental goals are difficult to realize at present. Some hot topics, such as possible trade-offs between economic and other sustainability goals discussed in the 'Major Problems' section, value for domestic markets even if products are not compatible with export specifications and triple-bottom-line accounting, are all important problems for green food development. With the further development of China's green food industry, these problems are worthy of deep consideration and some deeper environmental goals need to be realized in China.

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Book Review

Organic Farming: An International History. Edited by William Lockeretz. CABI, Wallingford, Oxfordshire OX10 8DE, UK. 2007. 282 p. $150.00, Euro 100, ISBN 978-0-85199-833-6, cloth cover.

Organic farming and food systems have experienced a phenomenal growth over the past three decades. Since food consumption is a relatively inelastic phenomenon for most industrialized countries, this major growth represents a conversion in purchase and eating habits, and the organic food sector today represents over $30 billion (Euro 20 billion) in global annual sales. *Organic Farming: An International History* comes at an appropriate time to chronicle the growth of this industry and discuss the factors that are likely to preserve the trend.

William Lockeretz is a well-recognized expert in this area, as one of the first researchers to compare organic and conventional production systems and outputs on farms in the US. He has also been active in the global arena since the organization of IFOAM, an international umbrella group that urges and oversees the development of uniform standards that are recognized and accepted. With his many contacts in Europe, Dr Lockeretz is ideally placed to entice the world's experts in organic farming to contribute to what has become a well organized and superbly edited volume.

An introductory chapter by the editor quickly traces the history of organic farming, while in chapter 2, Gunter Vogt describes a system that grew in response to 'a crisis in the form of soil degradation, poor food quality and the decay of rural social life and traditions' (p. 9) following World War II. He describes the focus on biological systems in the German- and English-speaking countries, including a foundation in science in the UK, Germany and the US. The biodynamic movement launched by Rudolph Steiner was a part of this thrust. An intriguing detail was the early support of biodynamic farming by highly placed Nazi leaders in Germany.

In chapter 3, Michael Sligh and Thomas Cierpka discuss the values that were imbedded in the philosophy and implementation of organic farming, most recently incorporated into the four principles of IFOAM: health, ecology, fairness and care. In addition to production methods and safe food, systems were designed for environmental stewardship and accountability and fairness throughout the system. A unique blend of science that combined farmer experience with experiment station rotations is described by Deborah Stinner in chapter 4. Many of the key advances came from private and non-profit institutes, as conventional universities were slow to embrace research on this alternative method of food production. Government support in Germany, Denmark, and the US soon followed, but research investments were minimal compared to those in chemical agriculture. Today the emphasis is on soil ecology, nutrient cycling, pest management, genetic and cultural resistance and food quality parameters. To date, organic livestock production has received far less attention than organic crops.

Organic practices and systems have evolved over time in response to farmer experience and science inputs, according to Urs Niggli (chapter 5) who is the Director of the FiBL Research Network in Switzerland and Germany. Modern approaches to organic crop production include field sanitation, tolerant varieties and mixtures, intercropping, nutrient cycling and approved crop protection agents. In several countries, government subsidies have been crucial to the growth of organics, as described by Susan Padel and Nick Lampkin in chapter 6. This became both more complicated and more universally available with the advent of organic alternatives within the Common Agricultural Policy (CAP) enacted by the European Union in 2003 to reform support of the farm sector. Concurrently, the marketing options for organic foods were developing and maturing as described in chapter 7 by Jessica Aschmann and colleagues in Germany and Italy. There was a shift in the consumer demographic to a wider market, and essential to growth were the standards that were initially national and later became rationalized through the IFOAM as discussed in chapter 8 by Otto Schmid. The history of IFOAM as chronicled by Bernward Geier in chapter 9 was central to recognition and confidence for organic foods in the marketplace, and this group continues to be recognized as the international umbrella for individual certifiers, both public and private.

The importance of national farmer organizations and research groups that are especially organized to fit local context and resources is demonstrated by descriptions of The Soil Association in U.K. (Philip Conford and Patrick Holden, chapter 10), Ecological Farmers Association and KRAV in Sweden (Inger Källander, chapter 11), MAPO in Argentina (Dina Foguelman, chapter 12), NASAA in Australia (Els Wynen and Sandy Fritz, chapter 13) and the research network FiBL (Urs Niggli, chapter 14). Another major advance was the emergence of the Organic Trade Association that brought together private organizations in the processing and marketing sector, discussed by Katherine DiMatteo and Grace Gershuny in chapter 15.

A perspective on the future was assembled by Bernward Geier and several other authors from the book (chapter 15). There is a summary of original core principles that have stayed intact, along with some key changes that have been

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necessary and several unresolved issues that continue to be debated in organic circles. This last group includes the quest for uniquely adapted cultivars for special organic farming conditions and systems, the potentials for recycling urban waste including human manure and urine, the major disagreements over organic food quality, and the need to design agroecosystems that are more resilient and resource efficient, and thus more closely resemble natural systems. The industrialization of organic production and recent dominance of major multinational corporations in marketing, what is often called 'Big O', are major concerns to founders and purists in the organic farming and food sector.

One quality of *Organic Farming* that makes the book especially appealing to a North American audience is the preponderance of European authors and perspectives, an under-appreciated dimension in the history of organic farming. One could argue that the virtual absence of history and information from East Asia has created a Eurocentric volume that minimizes the valuable contributions to non-chemical systems that originated in China, Korea and Japan, a factor that was recognized by the editor. Overall, this history is comprehensive and well referenced. The chapters are written by experts in the organic farming and food sector. For a farmer, student, or researcher, this book provides most of what is needed to understand the modern origins and current practices in organic farming. The editor has done an exceptional job of bringing together solid information and documentation that gives a strong practical as well as theoretical foundation to organic farming today. The tone of the book provides direct contrast to another book that is highly skeptical about the future of organic farming (Kirchmann and Bergström[1]). However, there is strong confirmation of the Lockeretz conclusions about the value of organic farming systems and foods in the most recent edited volume on the current science and practices of this important sector of agriculture (Francis[2]). The serious reader is directed to all three books to access a range of opinions as well as documented facts about the past and future of organic farming and foods.

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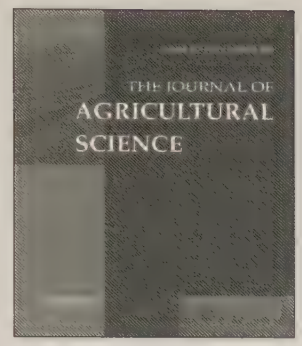

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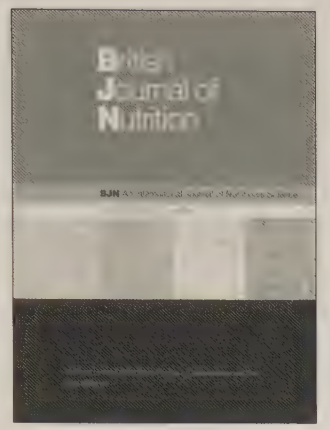

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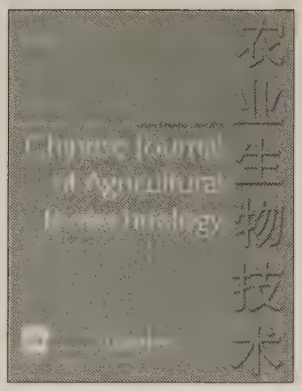

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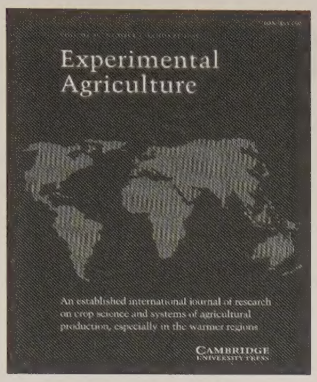
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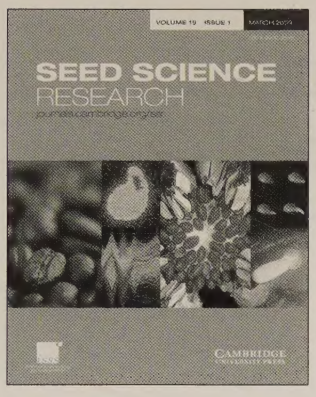

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1. Leopold, A. 1991. The farmer as a conservationist. In S.L. Flader and J.B. Callicott (eds). The River of the Mother of God and Other Essays by Aldo Leopold. University of Wisconsin Press, Madison, WI. p. 255–265.
2. Brink, R.H. Jr, Dubach, P., and Lynch, D.I., 1960. Measurement of carbohydrates in soil hydrolyzates with anthrone. Soil Science 89:157–166.
3. Greenland, D.J., and Szabolcs, I., (eds). 1994. Soil Resilience and Sustainable Land Use. CAB International, Wallingford, UK.
4. Arshad, M.A., and Coen, G.M., 1992. Characterization of soil quality: Physical and chemical criteria. American Journal of Alternative Agriculture 7:25–31.
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